

A Case Study In Public Data Release: Flight Path of Malaysia Airlines MH370





On Public Data Release



May 27, 2014, Malaysia DCA and Inmarsat released satellite communication logs for flight MH370.

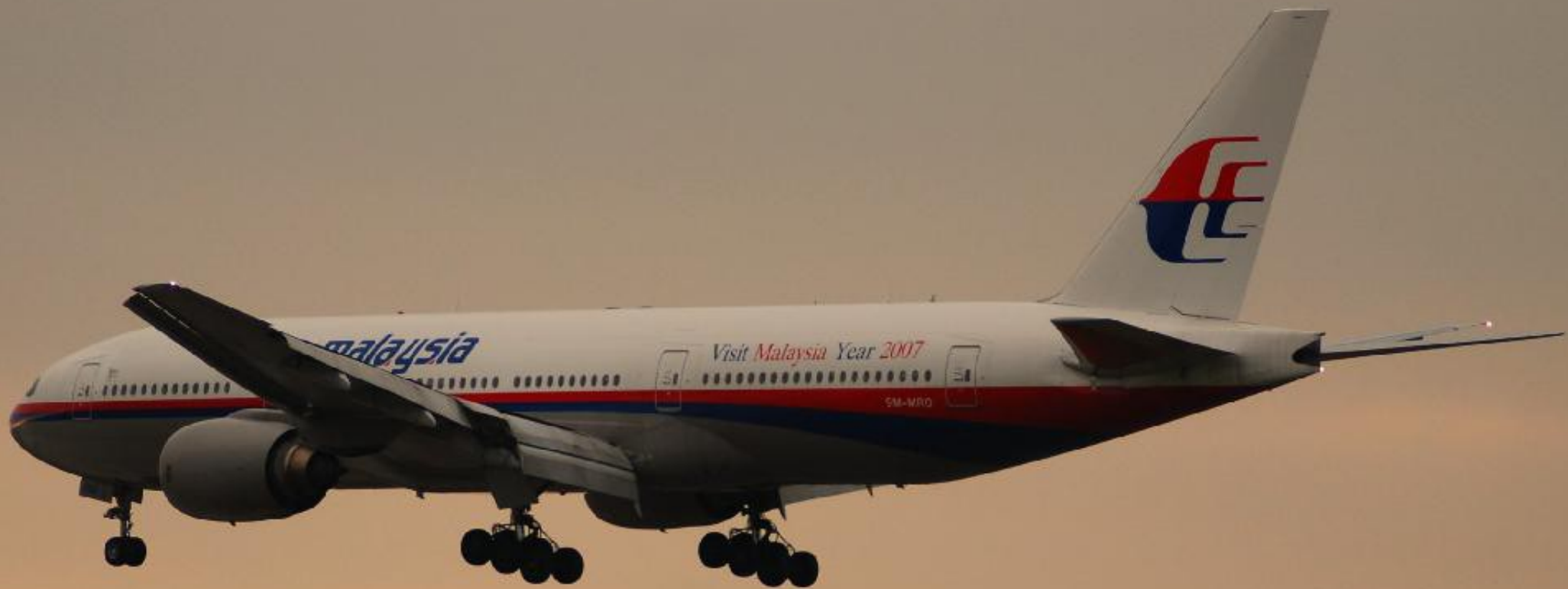
“The goal of publication is transparency, not verification”

Mark Dickinson, Inmarsat

“The data itself is barely understandable, very opaque and you cannot draw too much from it.”

“It is definitely not something someone can pick up and run with it and generate the same numbers.”

The purpose of this talk is to demonstrate otherwise.



I. Timeline

II. Satellite Communication System

III. Public data products and analysis

IV. Breaking News

V. Lessons learned

MH370
Departure
Kuala Lumpur
Mar 8, 2014

Flight Level 180



SID: PIBOS Alpha
Departure
Squawk 2157

Runway 32-Right

Holding Point Alpha-11
Hold Short Bravo

Taxi Standard Route

Taxiway B & L restricted to aircraft with wingspan of 79' (24m) to 117' (36m) only.



A seemingly ordinary air disaster –

March 8, 2014 (MT) Malaysia Airlines Flight MH370, a Boeing 777 jet on a flight from Kuala Lumpur to Beijing, has lost contact. All indications are that it has crashed in the South China Sea between Malaysia and Vietnam.

**[BOAC 781 (1954); Flying Tiger 739 (1961);
Varig PP-VLU (1979); Air France 447 (2009)]**





07:24 (MT) – MAS issues media statement

MEDIA STATEMENT released at 7.24am/8 Mar 2014 MH370 Incident

Sepang, 8 March 2014: Malaysia Airlines **confirms that flight MH370 has lost contact with Subang Air Traffic Control at 2.40am, today (8 March 2014).**

Flight MH370, operated on the B777-200 aircraft, departed Kuala Lumpur at 12.41am on 8 March 2014. MH370 **was** expected to land in Beijing at 6.30am the same day. The flight **was** carrying a total number of 227 passengers (including 2 infants), 12 crew members.

Malaysia Airlines is currently working with the authorities who have **activated their Search and Rescue team to locate the aircraft.**



***However, there is one small
detail ...***

***Unbeknownst to anyone,
the plane is
STILL IN THE AIR!***

I. Timeline of MH370

Planned Flight

16:00 to 24:19 UT,
March 7, 2014

Note: Malaysia and
China timezone are 8
hours ahead of UT –
hence March 8 MST.



16:00 UT – Passengers boarding MH370 at Kuala Lumpur airport satellite terminal, gate C1. SATCOM activated. ACARS message.

KUL - Satellite Terminal



What are ACARS messages?

**16:29 UT - Plane pushes back from gate.
ACARS message.**



**16:42 UT - Takeoff for Beijing, runway 32R
6 hour flight. ACARS messages.**



**17:07 UT - MH370 cruising at 35,000 feet
469 knots GS, heading for waypoint IGARI.
Last ACARS message.**



17:19:29 UT – KL Radar signs off; transfer to HCM FIR. Last voice communication.



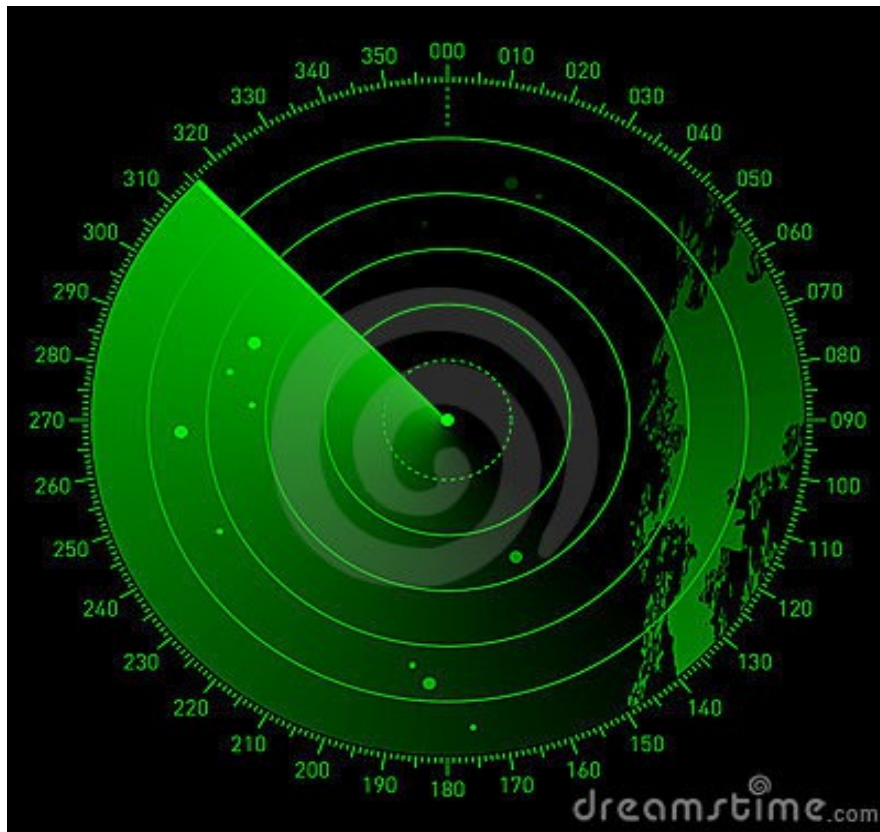
17:19:24 (ATC) “Malaysian three seven zero contact Ho Chi Minh 120 decimal nine. Good night.”

17:19:29 (MAS 370) “Good night, Malaysian three seven zero.”

17:20:31 UT – Arrival at waypoint IGARI (“Transfer of Control Point” - TCP)



17:20:33 UT – Aircraft symbols start dropping off Secondary Radar at HCM, KL, and Bangkok ATCC. Plane becomes invisible to ATC.

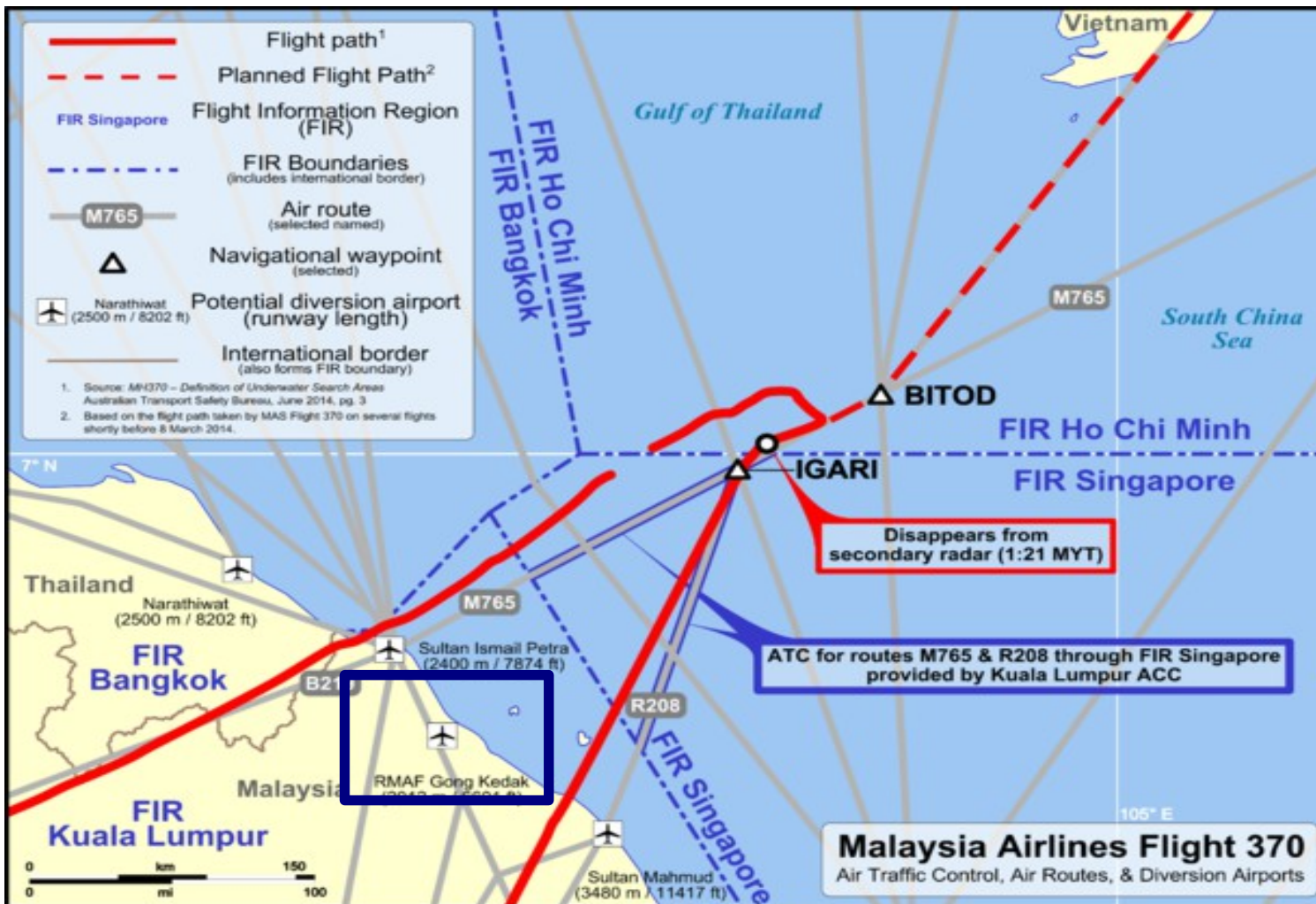


Primary Radar

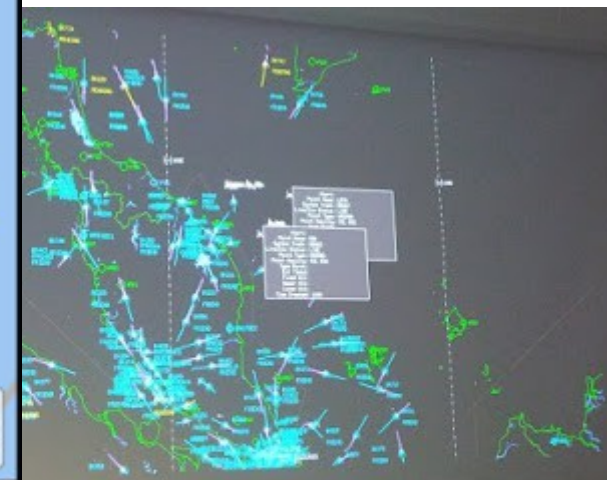


Secondary Radar

17:23 UT – Plane is still tracked by military primary radar. Plane banks left; heads along Malaysia-Thailand border.



Martello S743D



17:37 UT – Next ACARS message due from aircraft - never sent



1 minute later

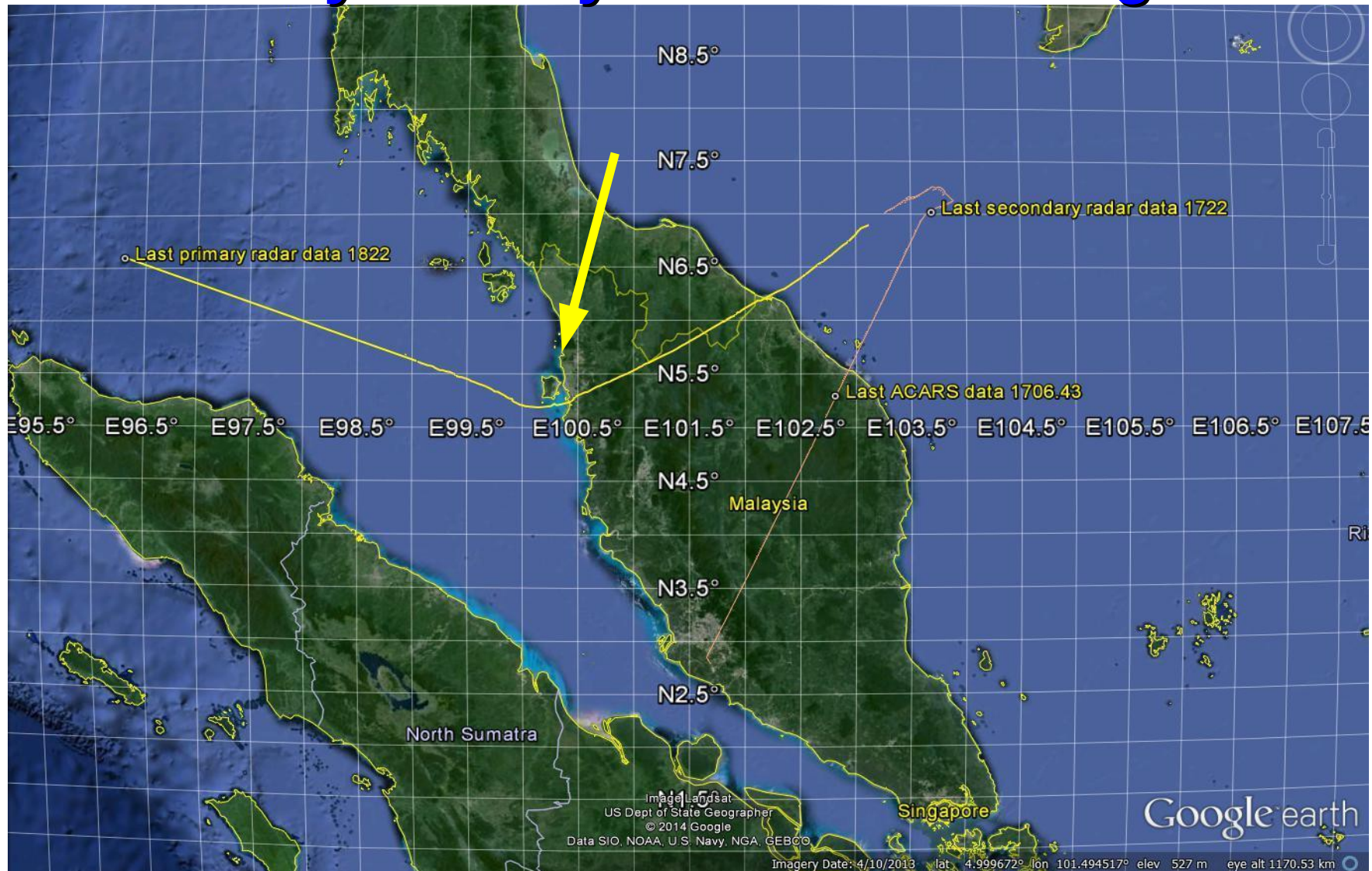
17:38 UT – HCM and KL ATC begin communicating r.e. location of MH370. Four hours pass before it is fully established that the plane is missing.



Event

17:38:19 Ho Chi Minh first enquired about MH370, informed KL-ATCC that verbal contact was not established with MH370 and radar target was last seen at BITOD.

17:51 UT – Plane passes S of Penang Island and turns WNW along Strait of Malacca. Now being tracked by military radar on Penang Island

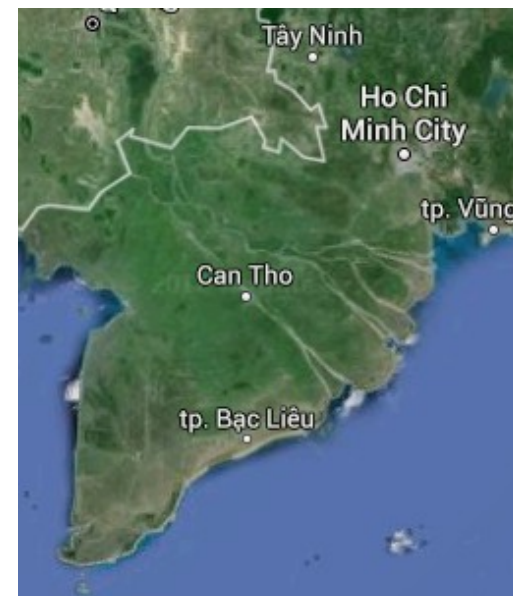


18:04 UT – ACARS message sent from ground to aircraft via satellite; no response. SATCOM inoperative.

18:03 - No Response to Ground to Air DATA-2 ACARS Data. Link lost at sometime between 17:07:48 and here.

7/03/2014 18:03:41.405	IOR-P10500-0-3859	IOR	305	10	P-Channel TX	0x71 - User Data (ISU) - RLS
7/03/2014 18:03:41.405	IOR-P10500-0-3859	IOR	305	10	P-Channel TX	Subsequent Signalling Unit

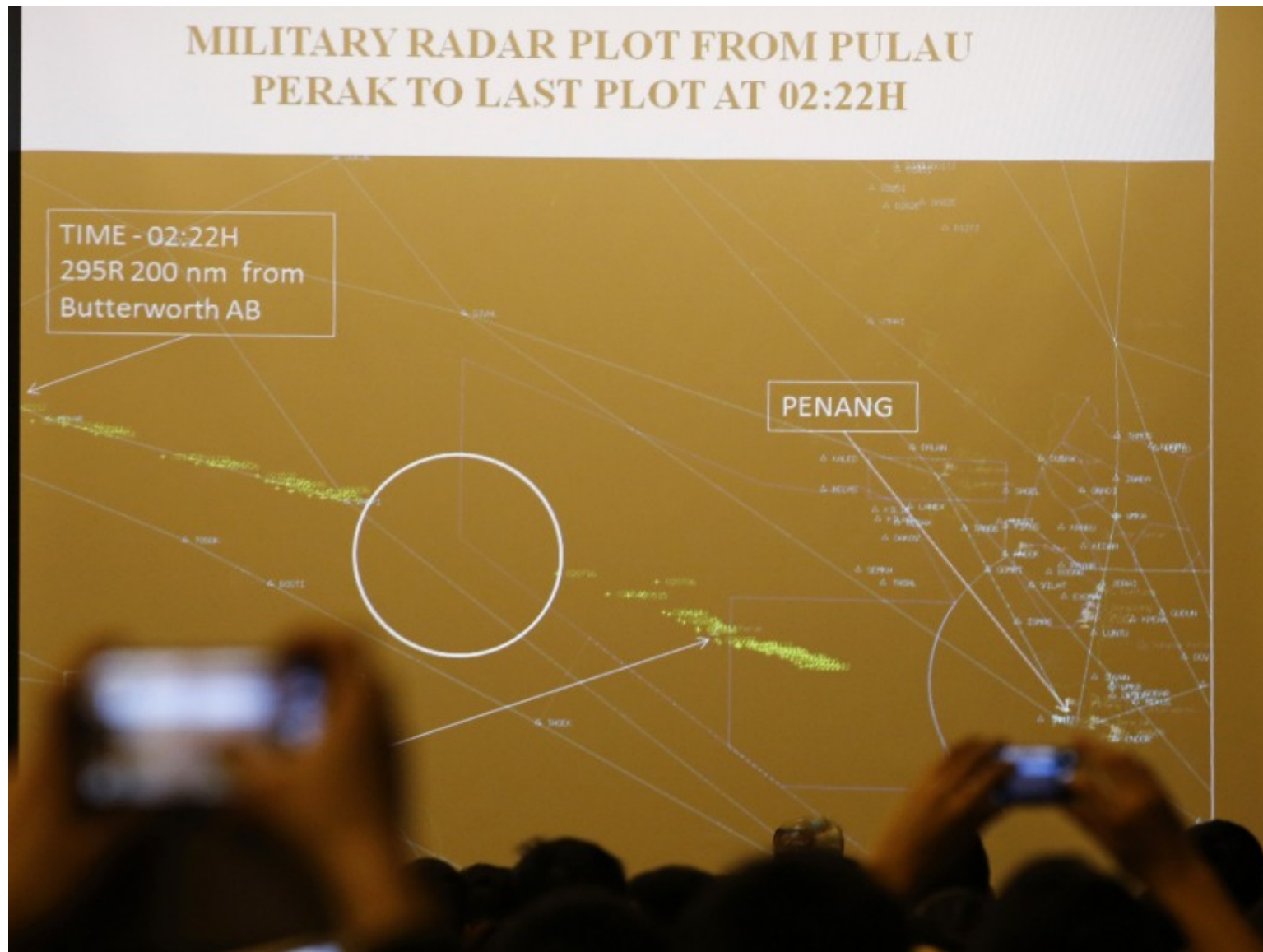
***“PLS CONTACT HO CHI MING ATC ASAP
THEY COMPLAIN CANNOT TRACK YOU
ON THEIR RADAR”***



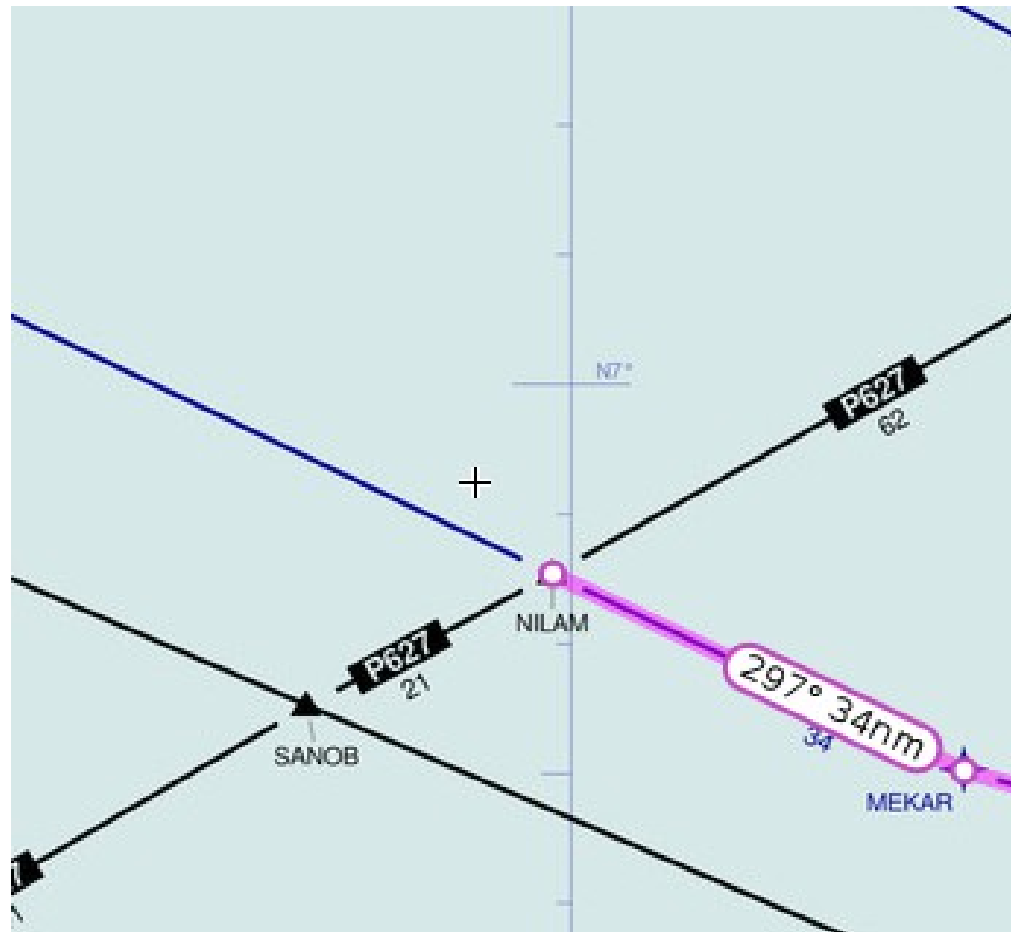
**18:12 UT – Plane reaches waypoint VAMPI;
begins following airway N571**



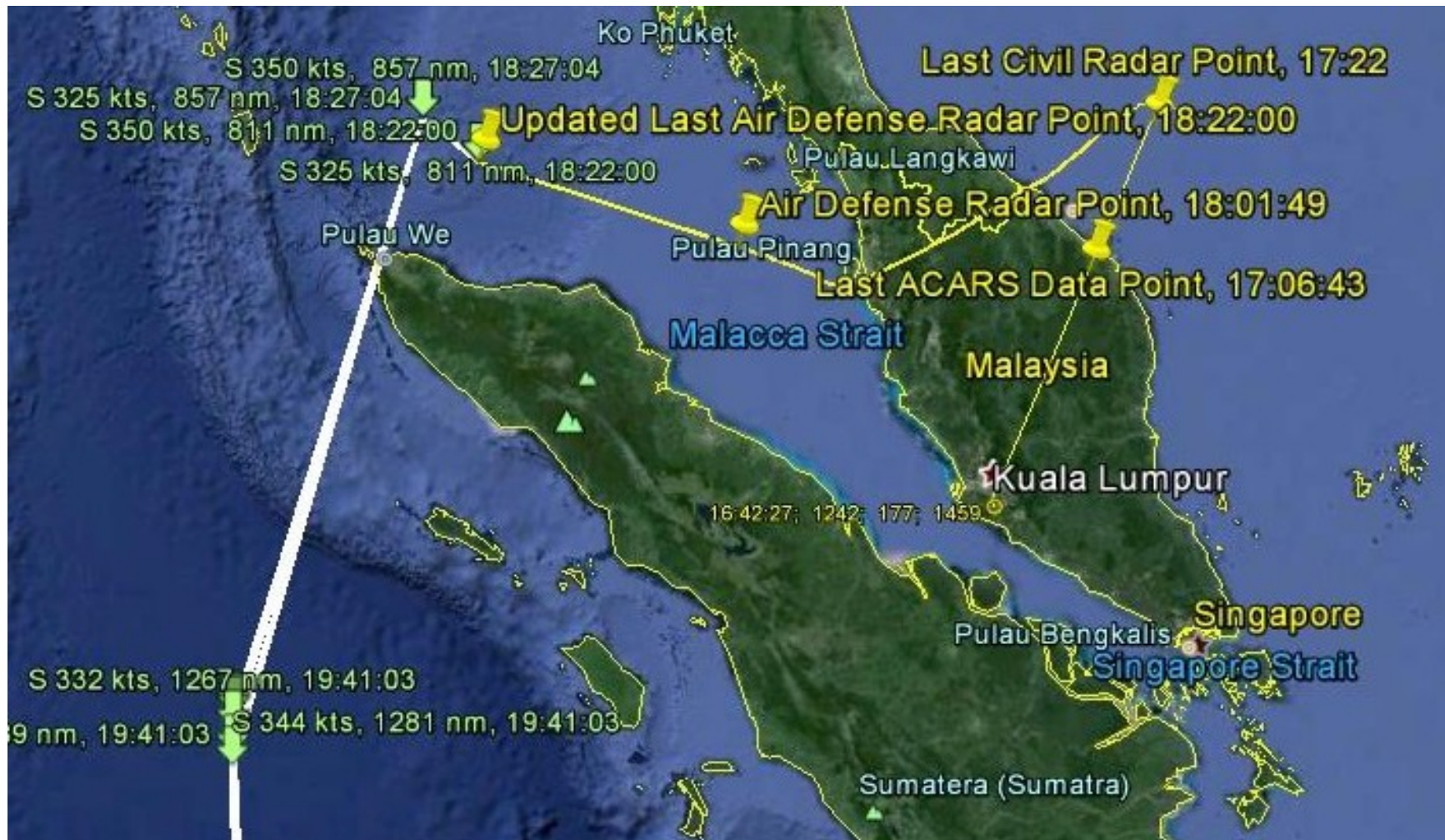
18:22 UT – Plane passes out of range of military primary radar. Plane invisible to all.



18:25 UT – SATCOM reactivated; logs on to satellite network. Plane appears to be continuing WNW track



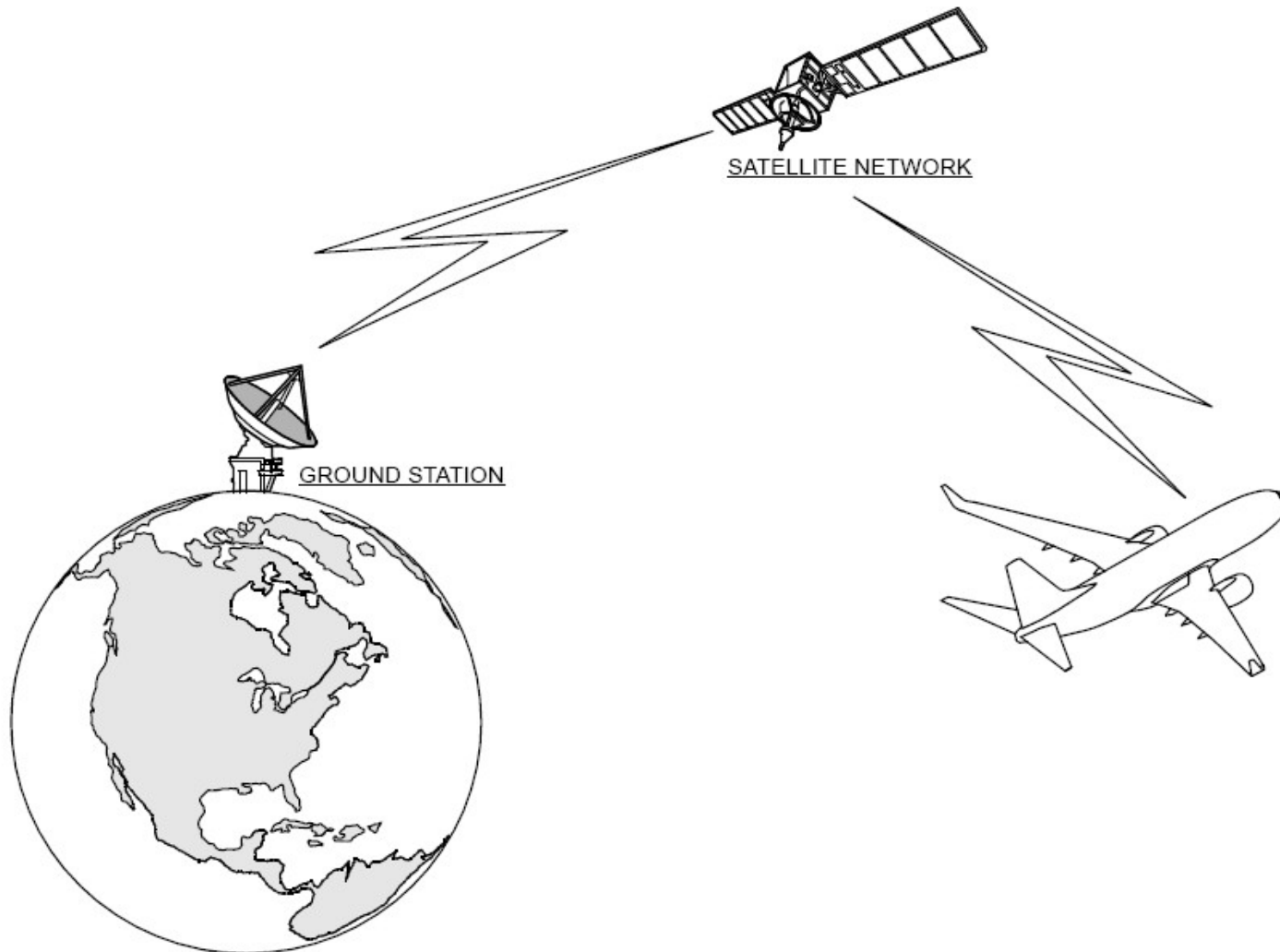
18:28 – 18:39 UT – Sometime in here plane makes sharp turn South



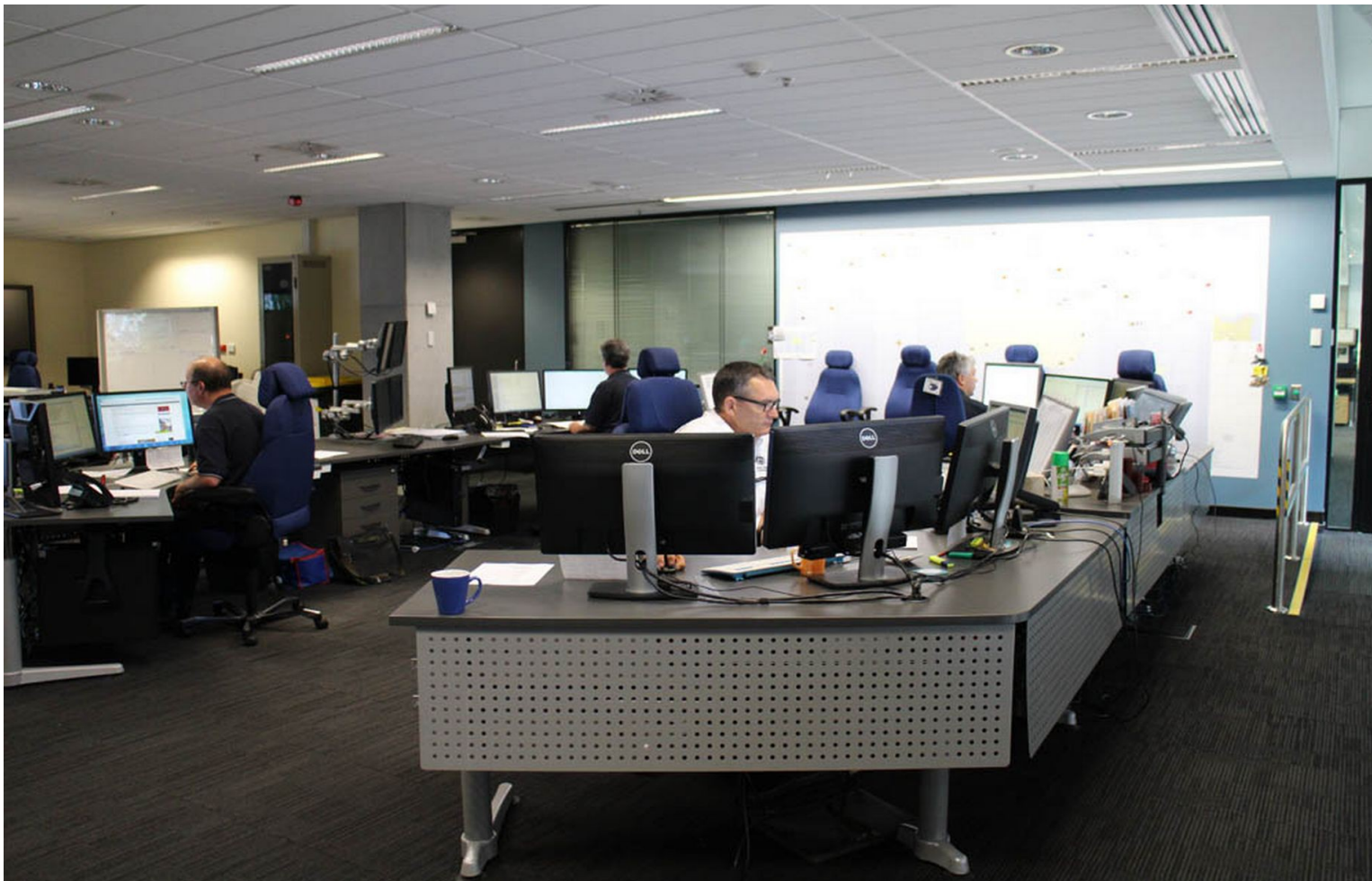
18:40 UT – Satellite call from Malaysian Airlines to MH370 attempted. SATCOM acknowledges, but call not answered.



19:41 UT and hourly thereafter – ground station send “keep-alive pings” to aircraft SATCOM; acknowledgement returned.



21:30 UT – KL Rescue Coordination Center activated



22:30 UT – Plane is overdue in Beijing

International				
航班号 Flight	始发站 From	计划到港 STA	预计到港 ETA	备注 Remarks
MH370 CZ	吉隆坡 Kuala Lumpur	06:30		Delayed
CA822	普吉 Phuket	07:50	08:25	Arrived
11	阿布扎比 Abu Dhabi	08:50	10:10	
1720 CA6220	法兰克福 Frankfurt	09:30	08:50	到达 Arri
1912 SK9512	斯德哥尔摩 St	09:40	09:28	d
123315 CA50	首尔金浦 Seoul Gimpo	09:45	09:32	到达
7002	维也纳 Vienna	10:20	10:10	

23:10 UT – Malaysia Airlines makes second attempted phone call; same result





23:24 UT – MAS issues media statement

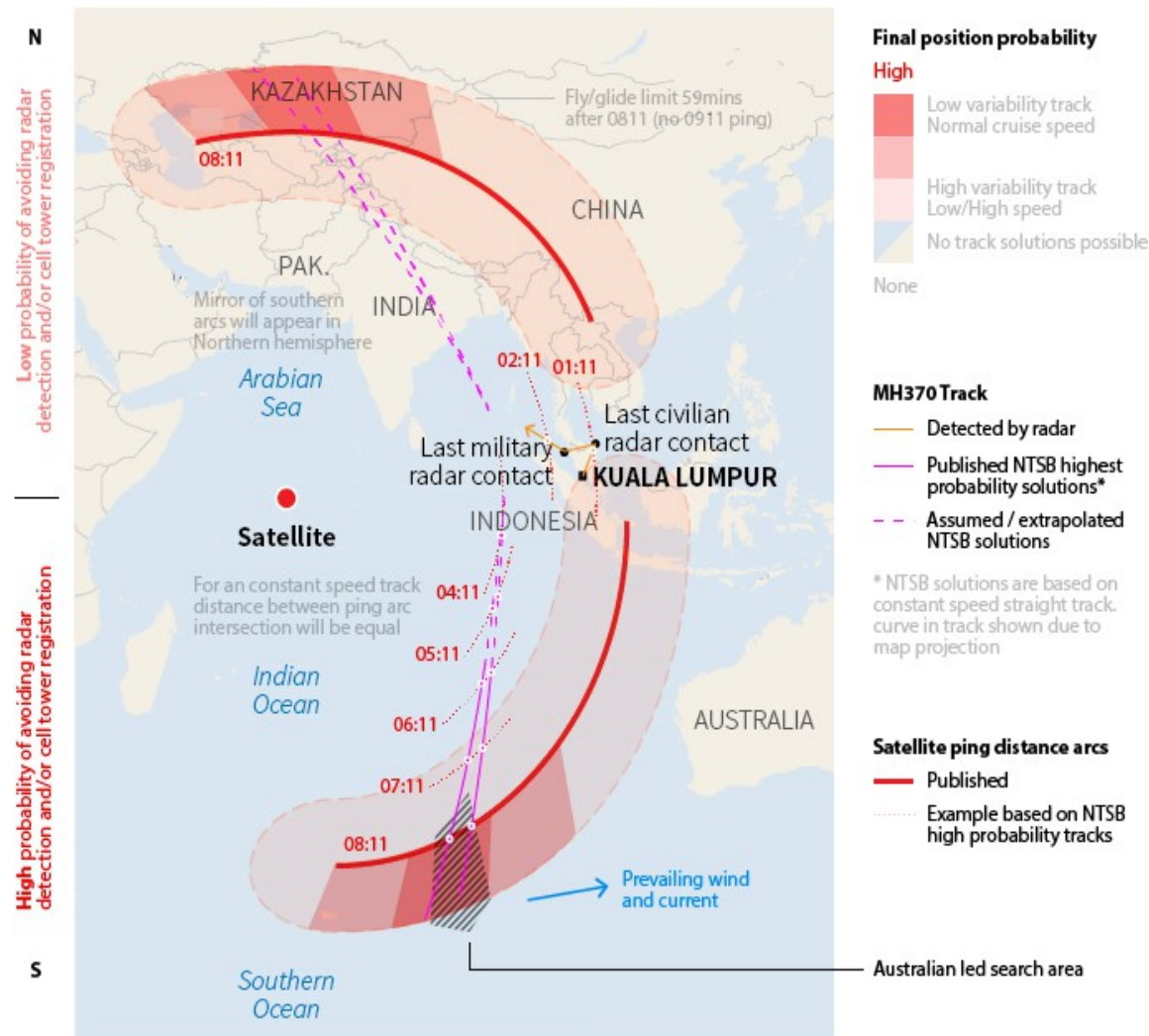
MEDIA STATEMENT released at 7.24am/8 Mar 2014 MH370 Incident

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Malaysia Airlines is currently working with the authorities who have **activated their Search and Rescue team to locate the aircraft.**

24:11 UT – Last ground-initiated “ping” exchange with aircraft (6th handshake)



Graphics based on BBC source with AMSA supplied data overlaid
All tracks, arcs and probability zones are symbolic only / not accurate

@_antialias_

24:19 UT – SATCOM sends another “Logon Request” message, but fails to complete the sequence. Possible engine flameout from fuel exhaustion; power loss; APU powerup.

00:19:29 - Log-On Request (reported as a Partial Handshake), initiated from the aircraft terminal

8/03/2014 00:19:29.416	IOR-R600-0-36F8	IOR	305	10	R-Channel RX	0x10 - Log-on Request (ISU)/Log-on Flight Information (SSU)	182
8/03/2014 00:19:31.572	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	0x11 - Log-on Confirm	
8/03/2014 00:19:32.212	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	0x40 - P-/R-Channel Control (ISU)	
8/03/2014 00:19:32.212	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	Subsequent Signalling Unit	
8/03/2014 00:19:32.852	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	0x41 - T-Channel Control (ISU)	
8/03/2014 00:19:32.852	IOR-P600-0-36FC	IOR	305	10	P-Channel TX	Subsequent Signalling Unit	

00:19:37 - Note that the following R-Channel burst at 00:19:37.443 is the last transmission received from the aircraft terminal

8/03/2014 00:19:37.443	IOR-R1200-0-36F6	IOR	305	10	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	
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Signal suggests plane is in a steep descent. Aircraft is presumed to have crashed near the location of the final transmission.

CNN Developing Story ...



II. Aircraft Communications Systems



Primary systems:

HF Radio

VHF radio

Mode S / ADS-B (“extended squitter”) transponder

Satellite Communications System (SATCOM)

Inmarsat

Iridium





Inmarsat

“International Marine Satellite” company

Started 1979 to provide
communications to ships
out of reach of land stations



Extended to cover land and air operations

Operates fleet of geostationary satellites.
Covers world up to 81 degrees latitude.

3 generations (I3 to I5) in operation

Inmarsat Services

Low bandwidth data

acars

SMS

Voice (phone) / Fax

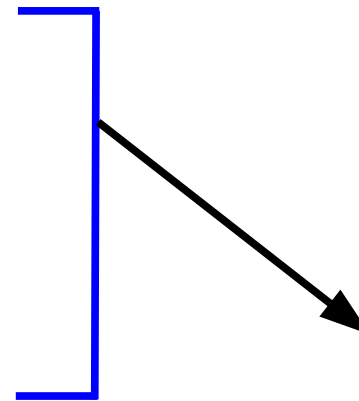
ISDN

Swift Broadband (internet; mobile circuit switched)

Service Providers

SITA (no VHF in China)

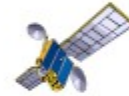
ARINC



Classic Aero-H
(Used by MH370)



Service Allocation



1525 - 1660.5 MHz **L-Band**



**Bandwidth about the same as a
dual frequency home wireless router**



System is constrained

Bandwidth is limited

Channel width 2.5 khz

Requires tight frequency control. For aircraft, Doppler effect is important. AES are required to adjust transmit frequency to compensate.

Timing is important

AES to GES R-channels are shared

“Slotted Aloha” - requires synchronization with GES to AES signal

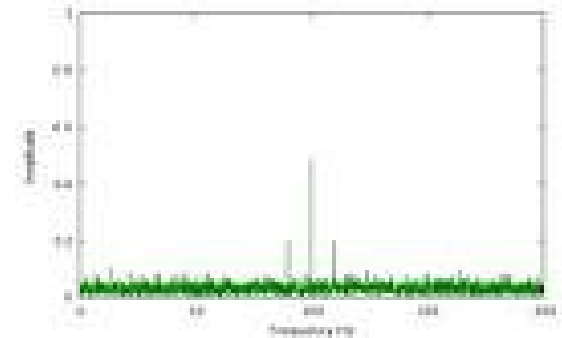
Pilot signals used extensively to monitor system



System Monitoring

“Burst Frequency Offset” (BFO) –
measures error in frequency from
AES to GES

1 hz resolution



“Burst Timing Offset” (BTO) –
measures error in signal timing
from AES to GES.

20 microsecond resolution

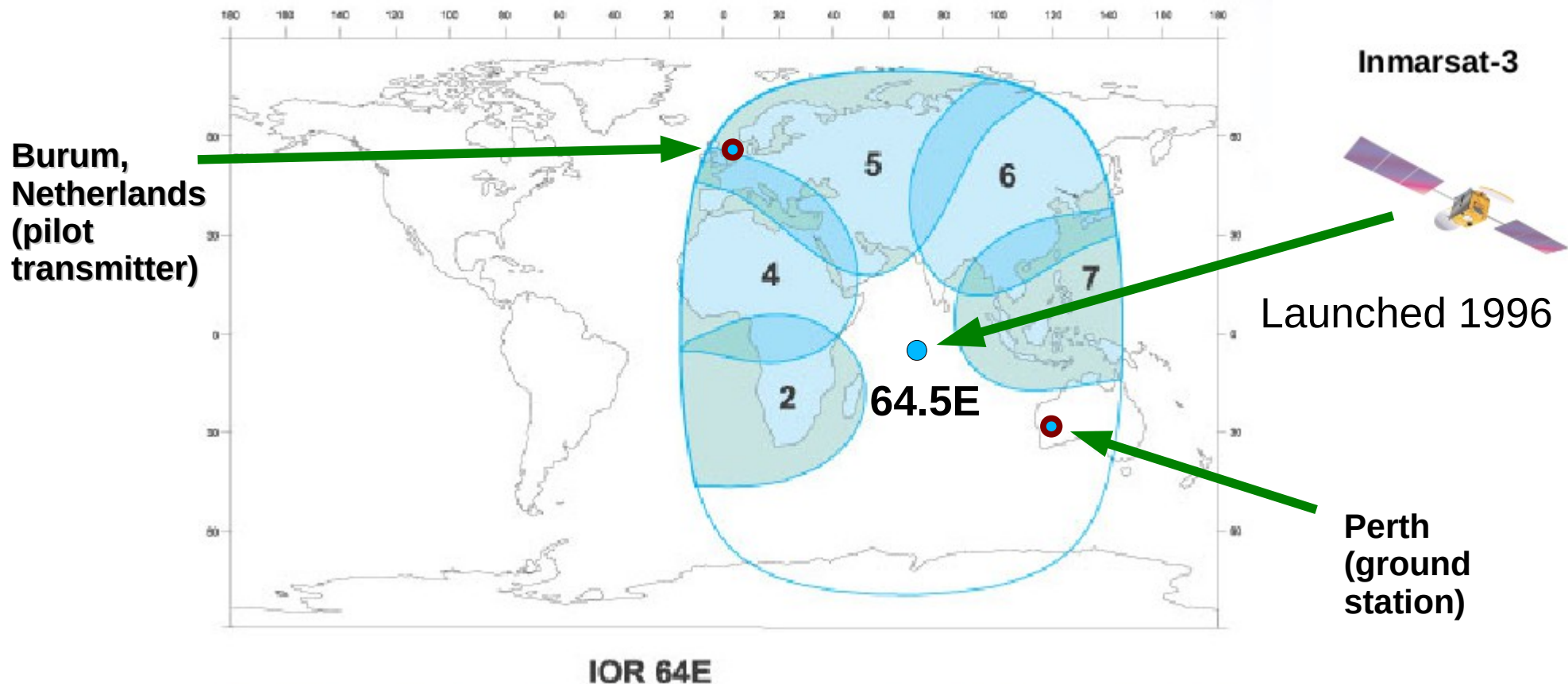


Both recorded along with data
packets at ground station in Perth,
Australia

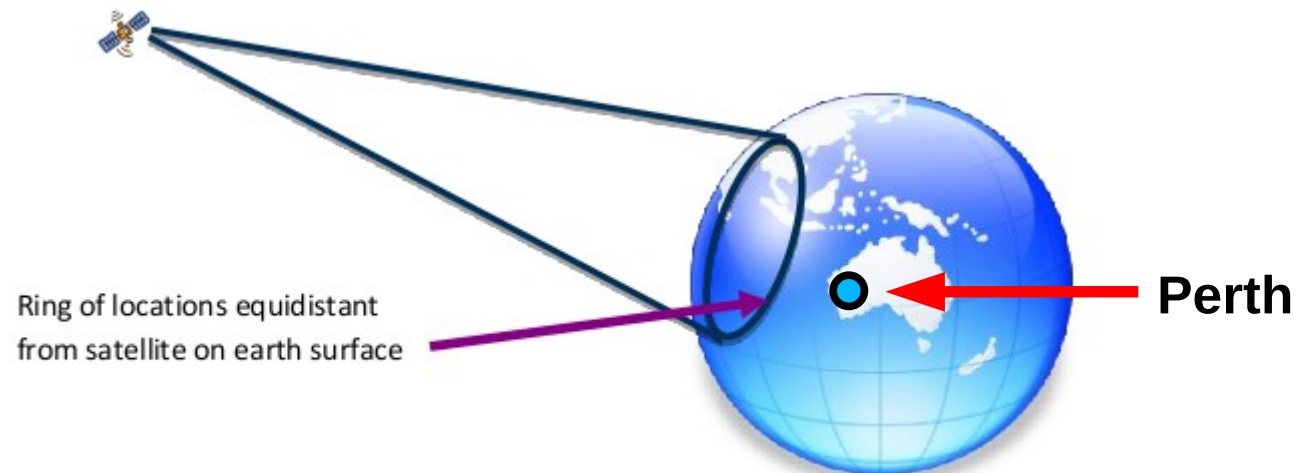
Inmarsat 3-F1

Indian Ocean Region

Inmarsat Generation 3

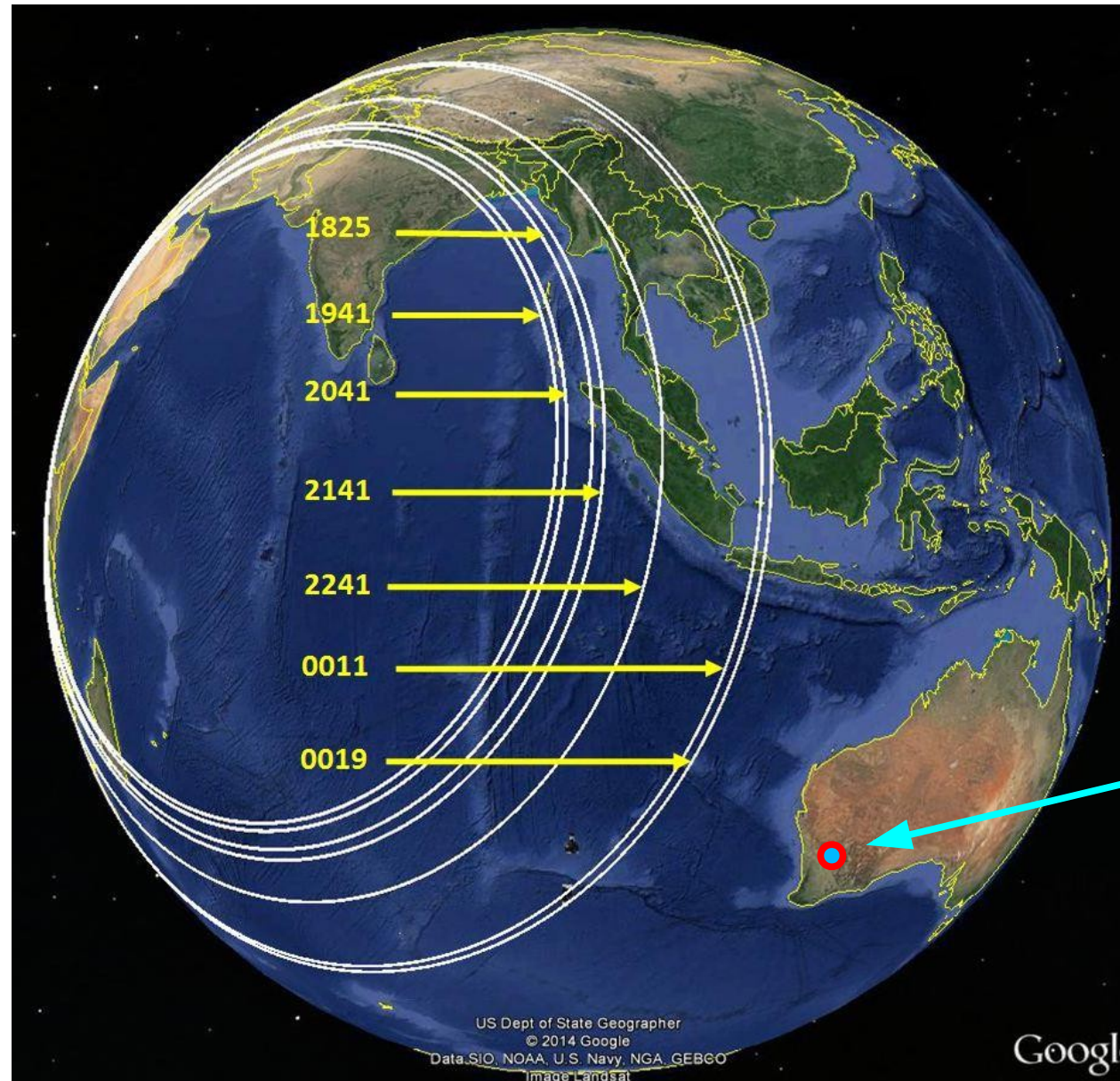


What we learn from BTOs



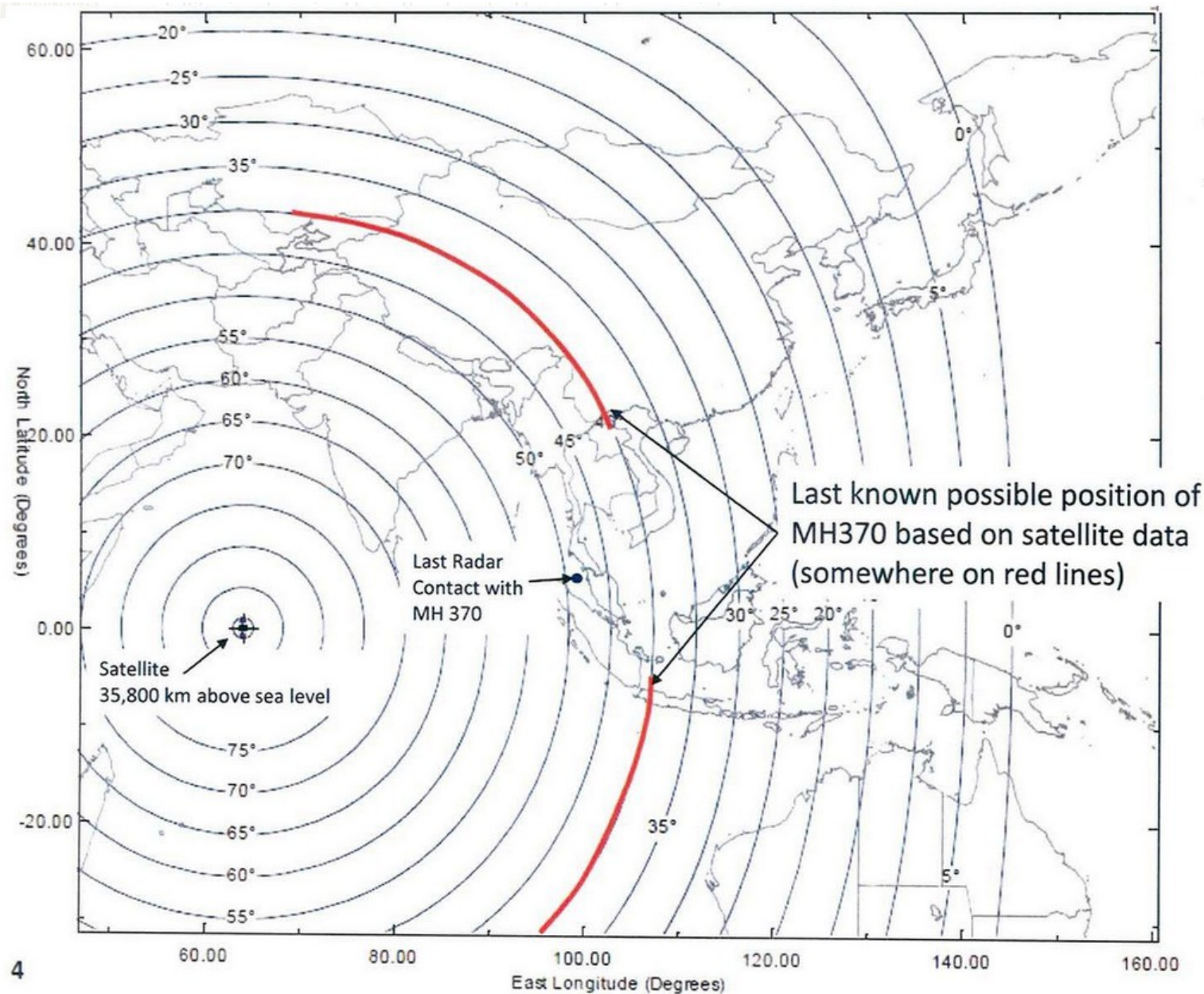
**Light travel time (round trip) is ~ 0.5 seconds.
BTO depends on aircraft location on Earth.
Even sensitive to altitude.**

Initial Analysis



Seven sets of BTOs define 7 “ping rings” from 18:25 to 00:19 (24:19).

However, both North and South Corridors are possible



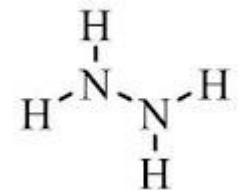


A Note on Geostationary Satellites

Main perturbation on geostationary satellite orbit due to Moon - causes inclination to increase.

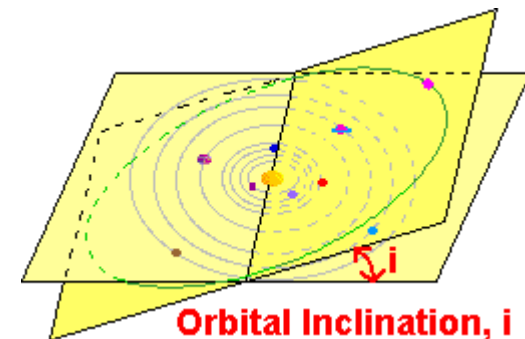


Satellites carry hydrazine for station-keeping; ~equal in mass to satellite at launch to control orbit.



3-F1 is an old satellite – inclination no longer controlled.

Inclination of 1.6 degrees on Mar 7, 2014 => Satellite oscillates above, below equator



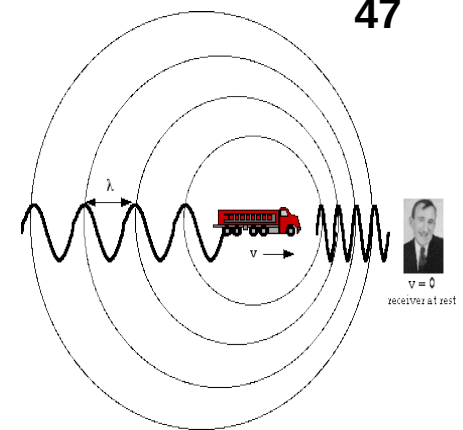
AES Doppler compensation mechanisms for aircraft

Doppler can be greater than 1 khz – exceeds tolerance of system.

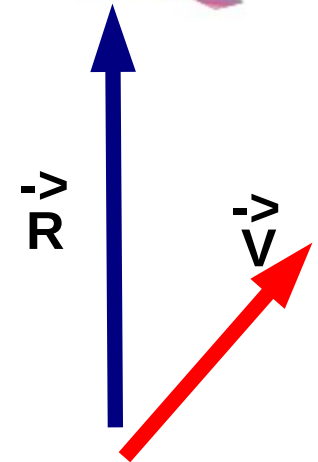
Compensation mechanism in MH370 SATCOM [Honeywell MCS-6000]

Use knowledge of plane's position, heading, and speed *along with knowledge of satellite position;* compute Doppler correction: $\vec{V} \cdot \vec{R}$

Assumes satellite is exactly over equator



Inmarsat-3

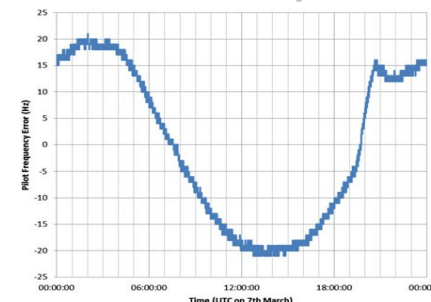


A fortuitous combination of circumstances

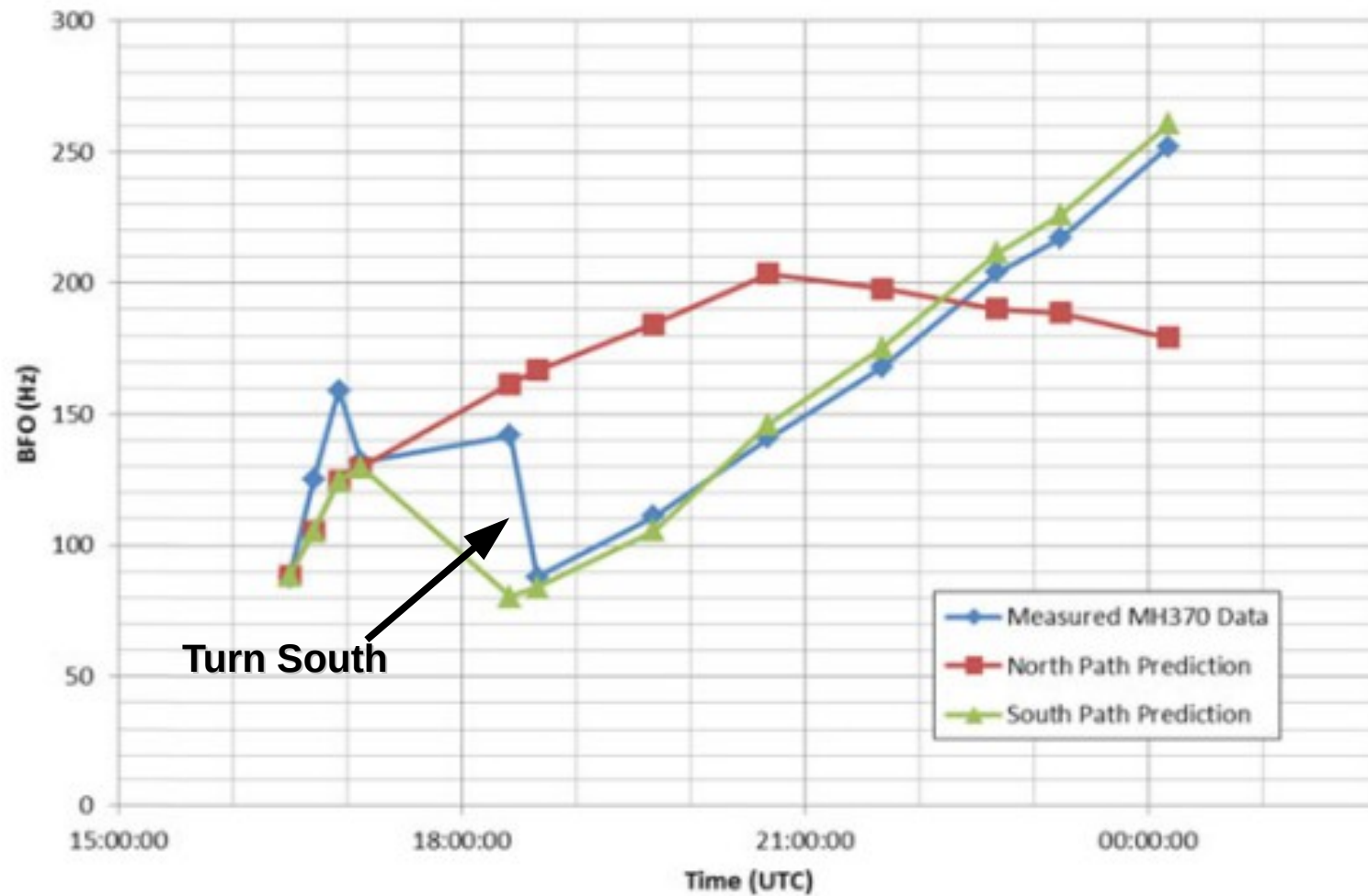


Because satellite orbit is inclined and AES assumes it is on the equator, the Doppler compensation is not perfect. ***Error includes contributions from satellite motion and from aircraft motion – sensitive to location and to speed & direction of travel of aircraft!***

Full BFO analysis is complex (contributions from GES AFC; satellite oscillator drift; satellite-GES Doppler)



Original BFO Analysis (cleaned up a bit)



III. Investigation By the Public

Can We Reproduce Inmarsat's Result?

Initially only figures available

Many forums for discussion

tmfassociates.com

pprune.org

duncansteel.com

jeffwise.net

reddit.com

twitter.com

airliners.net



Many people attempted to understand the ping ring; BFO plots poorly explained

Some features (e.g., AES Doppler) were decoded

Inaccuracies in published figures were detected

Public Data Release

Authorities (Malaysian MOT and Australian ATSB) have been exceedingly reticent in sharing information. However, we now have

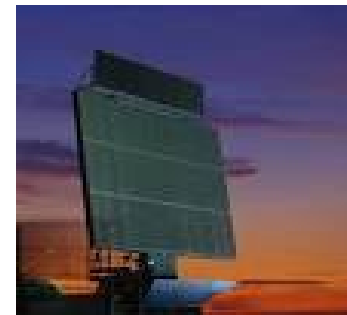
Inmarsat signal communication logs from 15:59 to end of flight

Documentation and calibration tables for BTO, BFO sufficient to understand and compute flight paths.

Missing

Complete military radar data

Calibration data from similar and historical flights



**Selex
ES RAT-31DL
3-D Phased array
Western Hill,
Penang Island**

Example page - communications log

Time	Channel Name	Ocean Region	GES ID (octal)	Channel Unit ID	Channel Type	SU Type	Burst Frequency Offset (Hz) BFO	Burst Timing Offset (microseconds) BTO
7/03/2014 18:28:14.904	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x62 - Acknowledge User Data (R-channel)	143	12480
18:39 - Ground Initiated to Air Telephony Call - Zero Duration (Not Answered)								
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data		
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x33 - C-Channel Assignment (Regularity)		
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data		
7/03/2014 18:39:52.907	IOR-P10500-0-386B	IOR	301	10	P-Channel TX	0x33 - C-Channel Assignment (Regularity)		
7/03/2014 18:39:55.354	IOR-3730-21000	IOR	305	6	C-Channel RX	0x30 - Call Progress - Test	88	
.....								
84 C-Channel and 2 P-Channel messages moved into separate below table (see appendix 1) to ease the reading of key events. C-Channel messages have no BTO values								
.....								
7/03/2014 18:40:56.354	IOR-3730-21000	IOR	305	6	C-Channel RX	0x30 - Call Progress - Channel Release	90	
19:41 - Handshake Request, with response								
7/03/2014 19:41:00.910	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 19:41:02.906	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	111	11500
20:41 - Handshake Request, with response								
7/03/2014 20:41:02.907	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 20:41:04.904	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	141	11740
21:41 - Handshake Request, with response								
7/03/2014 21:41:24.907	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 21:41:26.905	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	168	12780
22:41 - Handshake Request, with response								
7/03/2014 22:41:19.907	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x14 - Log Control - Log-on Interrogation		
7/03/2014 22:41:21.906	IOR-R1200-0-36ED	IOR	305	4	R-Channel RX	0x15 - Log-on/Log-off Acknowledge	204	14540
23:13 - Ground Initiated to Air Telephony Call - Zero Duration (Not Answered)								
7/03/2014 23:13:58.407	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x20 - Access Request/Call Announcement Telephone/Circuit-Mode Data		
7/03/2014 23:13:58.407	IOR-P10500-0-386B	IOR	305	10	P-Channel TX	0x33 - C-Channel Assignment (Regularity)		
7/03/2014 23:14:00.904	IOR-3737-21000	IOR	305	6	C-Channel RX	0x30 - Call Progress - Test	216	



Publications



www.malaysiaairlines.com/mh370 - Media releases

Malaysia Ministry of Transport on Facebook

Mar 22, 2014 - Cargo Manifest

<https://s3.amazonaws.com/s3.documentcloud.org/documents/1151153/mh370-cargo-manifest-and-airway-bill.pdf>

Mar 25, 2014 - Original BFO figures and explanation

[http://www.mot.gov.my/en/Newsroom/Press Release/Year 2014/Information Provided To MH370 Investigation by UK Air Accidents Investigation Branch \(AAIB\).pdf](http://www.mot.gov.my/en/Newsroom/Press%20Release/Year%202014/Information%20Provided%20To%20MH370%20Investigation%20by%20UK%20Air%20Accidents%20Investigation%20Branch%20(AAIB).pdf)

<http://www.inmarsat.com/wp-content/uploads/2014/03/Inmarsat-Differential-Doppler-Study.pdf>



Publications (cont.)



Apr 1, 2014 - Transcript of cockpit / ATC communications

http://www.bbc.co.uk/news/special/2014/newsspec_7440/transcript.pdf

Apr 27, 2014 - MH 370 Preliminary Report to ICAO

<http://www.dca.gov.my/MH370/Preliminary%20Report.pdf>

May 1. 2014 - HISHAMMUDDIN HUSSEIN - Actions taken on March 8.

http://www.abc.net.au/4corners/documents/2014/MH370/MH370Report_Actions_Taken.pdf

Maps

<https://www.facebook.com/HishammuddinH2O/>

Publications (cont.)



May 20, 2014 - Data Communication logs

<http://www.dca.gov.my/mainpage/MH370%20Data%20Communication%20Logs.pdf>

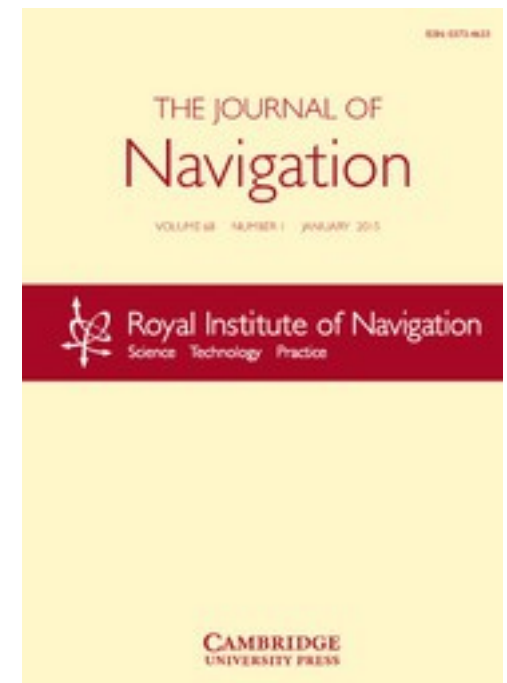
ATSB (Australia)

<http://www.atsb.gov.au/mh370.aspx>

Includes links to June 26, 2014 report "MH370 Definition of Underwater Search Areas" (with updates Aug 18, 2014, Oct 8, 2014, and Dec 3, 2015)

Oct 23, 2014 - "The Search for MH370" (Ashton et al.)

Journal of Navigation (2015), 68, 1



Publications (cont.)



INTERNATIONAL CIVIL AVIATION ORGANIZATION
A United Nations Specialized Agency

Jan 29, 2015 - “SAR Response to MH370”

[http://www.icao.int/APAC/Meetings/2015/APSARTF3/WP05 ICAO Brief on the SAR Response to MH370.pdf](http://www.icao.int/APAC/Meetings/2015/APSARTF3/WP05_ICAO_Brief_on_the_SAR_Response_to_MH370.pdf)



The Malaysian ICAO Annex 13
Safety Investigation Team for MH370

FACTUAL INFORMATION

SAFETY INVESTIGATION FOR MH370

Mar 8, 2015 - “Factual Information”

<http://mh370.mot.gov.my/>

Nov 30, 2015 - “Bayesian Methods in the Search for MH370”

http://www.atsb.gov.au/media/5733804/Bayesian_Methods_MH370_Search_3Dec2015.pdf

Malaysia Airlines MH370 Boeing B777-200ER (9M-MRO)
08 March 2014



By

The Malaysian ICAO Annex 13 Safety Investigation Team for MH370

Additional Documentation (partial)

Wind, temp models (Air Resources Laboratory):

<http://ready.arl.noaa.gov/gdas1.php>

<http://www.ecmwf.int/>

Magnetic declination maps (National Geophysical Data Center):

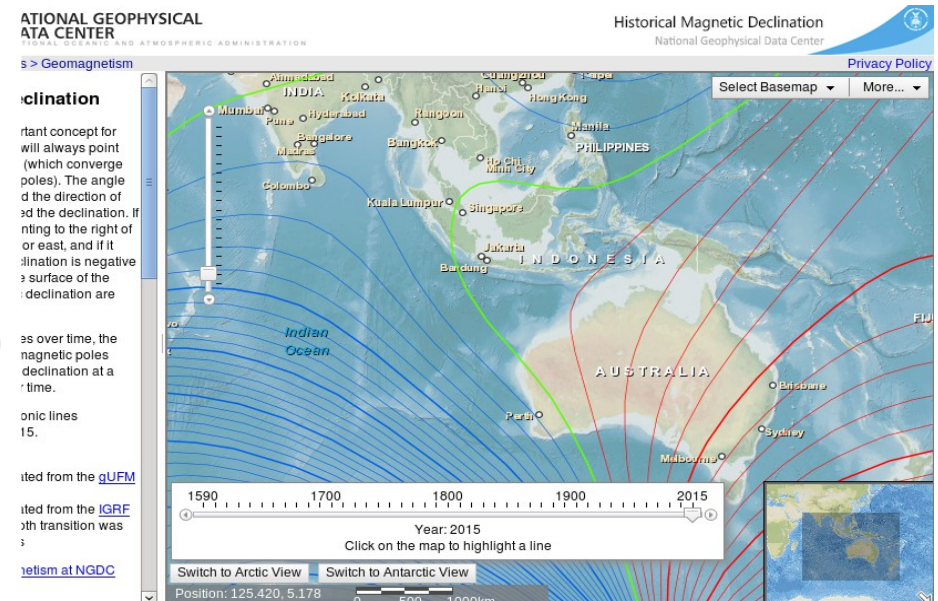
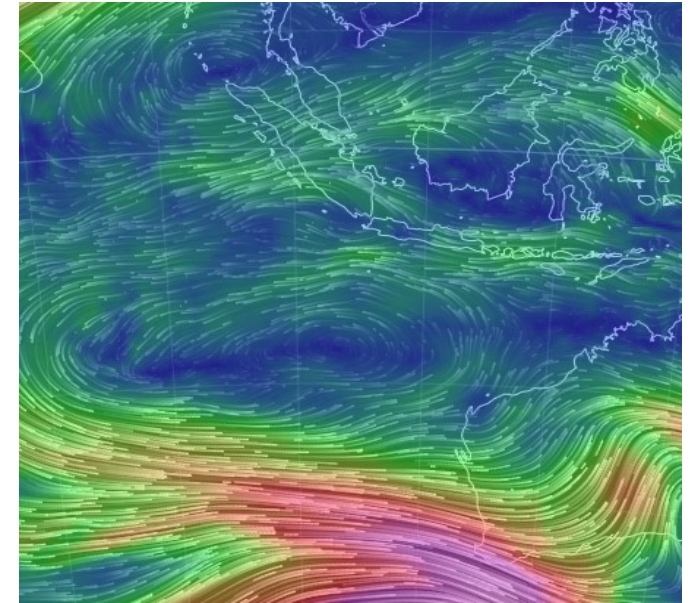
<http://www.ngdc.noaa.gov/geomag/models.shtml>

Satellite orbital parameters

<http://www.celestrak.com/>

Manual for Aeronautical Mobile Satellite (Route) Service (Inmarsat)

Boeing 777 Flight Crew Operations Manual



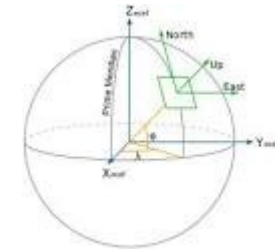
Additional details and information needed for models

Spheroidal Earth

Geodetic v. Geocentric latitude

B-777 autopilot modes

B-777 ranges v. fuel load



Amazing how much information is available on internet!



Public Data Analyses

Once full logs and documentation were released, many people began computing potential flight paths (in parallel to official investigation)

Key information not reverse-engineerable -

Perth GES AFC does not support negative latitudes!

Satellite frequency unstable – monitor by Burum pilot signal. Tables were released.

Some BTO and BFO values invalid



Table 4: Satellite and AFC values

Time UTC	($\delta f_{\text{sat}} + \delta f_{\text{AFC}}$) Hz
16:30:00	29.1
16:42:00	27.6
16:55:00	25.8
17:07:00	24.1
18:25:00	10.7
19:41:00	-0.5
20:41:00	-1.5
21:41:00	-18.0
22:41:00	-28.5
00:11:00	-37.7
00:19:00	-37.8

octave

[illegible]

Where do people “publish”?

dropbox

google docs

imgur

twitter

photobucket

bitmath.org

github

Personal websites



aqqa.org

AQQA REPORTS

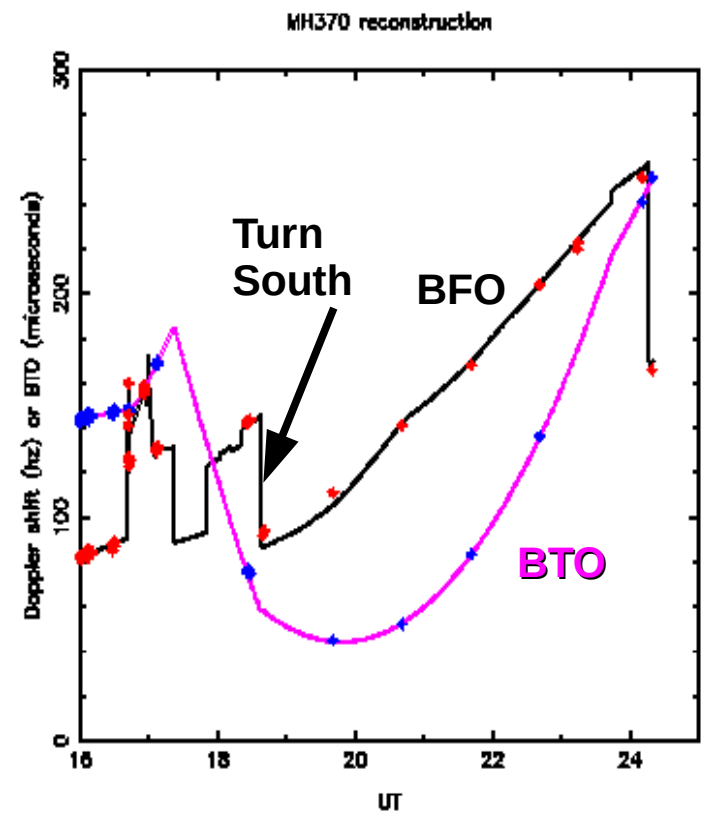
GODFREY MODEL



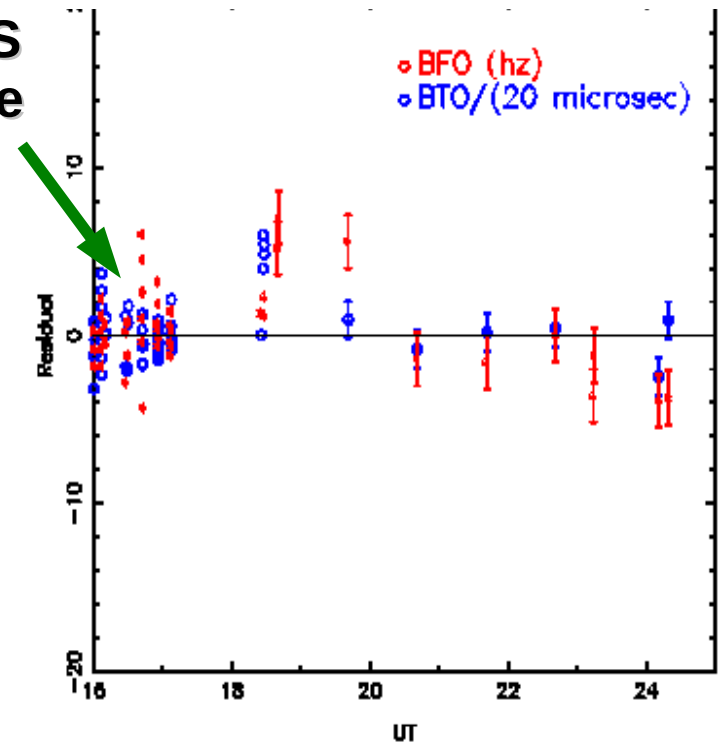
Example: Magnetic track mode



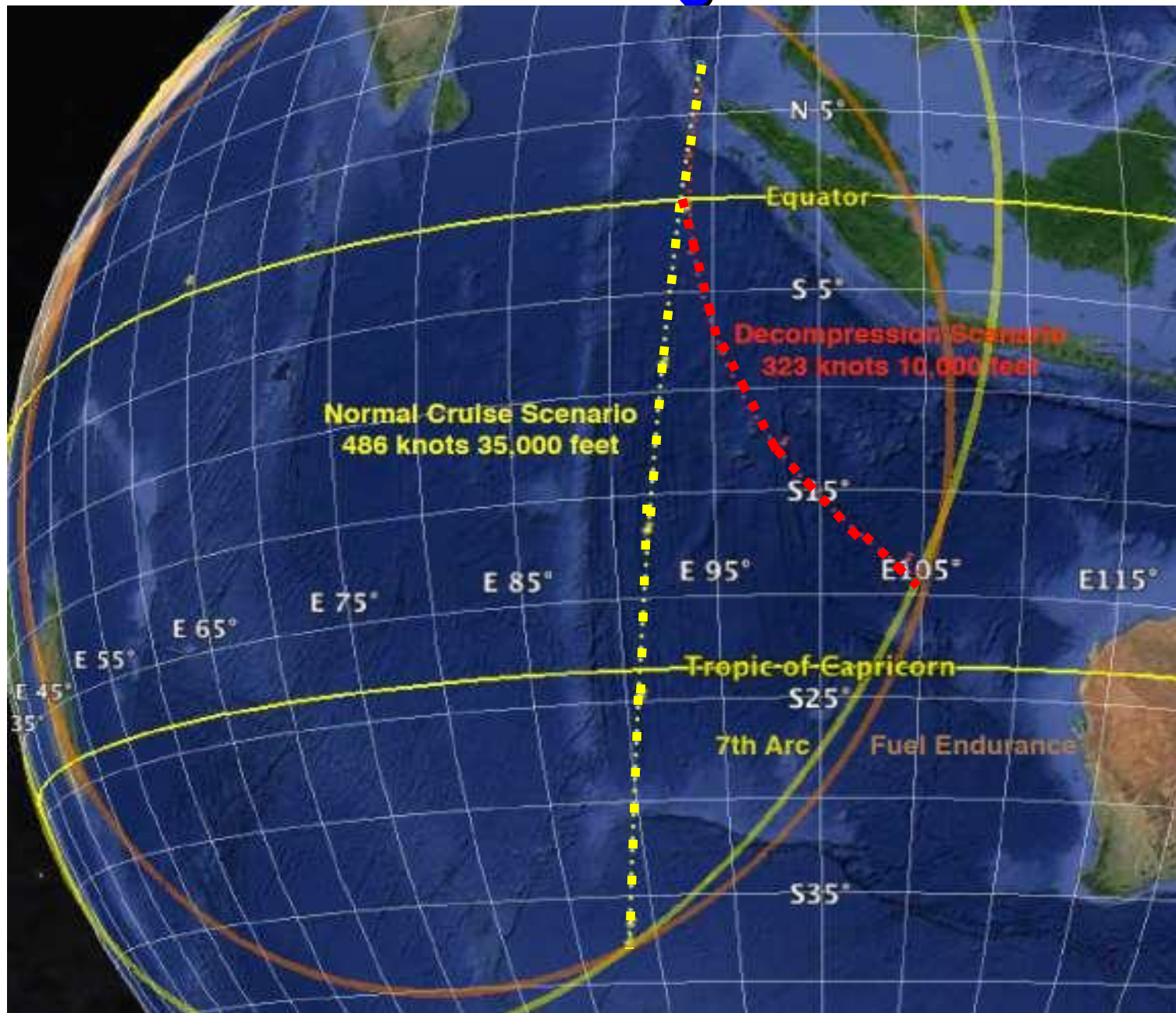
Final latitude -34 deg.



Initial ACARS
data calibrate
BTO, BFO
and validate
modeling



Example: Uncommanded Autopilot v. Active Pilot Flight Paths



A Sample of Reports

"An Analysis of the Inmarsat Data from MH370" - R. Cole, June 20, 2014.

"MH370 Search Area Recommendation" - The Independent Group, Sept 9, 2014. (**"We suggest you look *here*."**)

"The Location of MH370" - Bobby Ulich, Sept 25, 2014. (**"I suggest you look *there*."**)

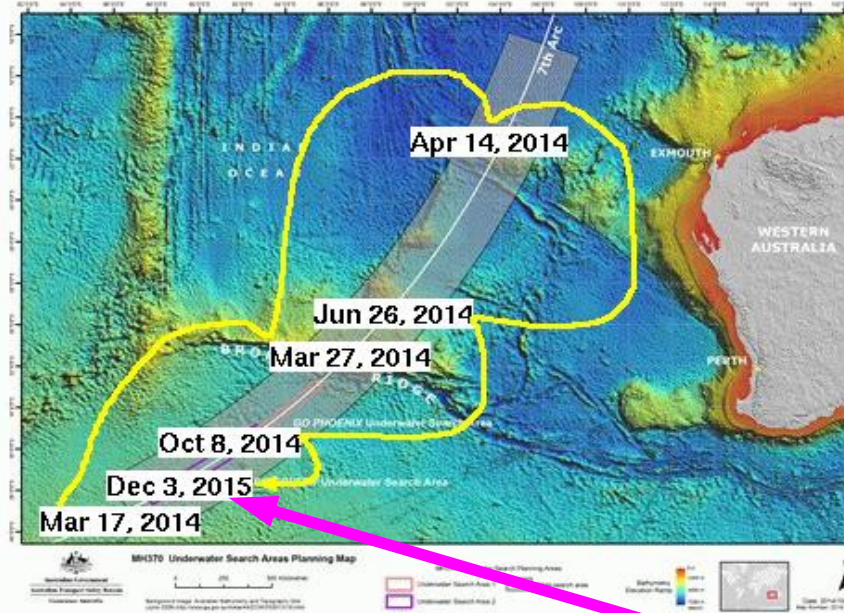
"Analytic Fuel Flow Model" - B. Martin, Mar 3, 2015.

"Some Observations on the Radar Data for MH370" - V. Iannello, Aug 18, 2015.

"MH370: On the possible interpretation of the abnormal BFO values" - Oleksandr N, Oct 1, 2015.

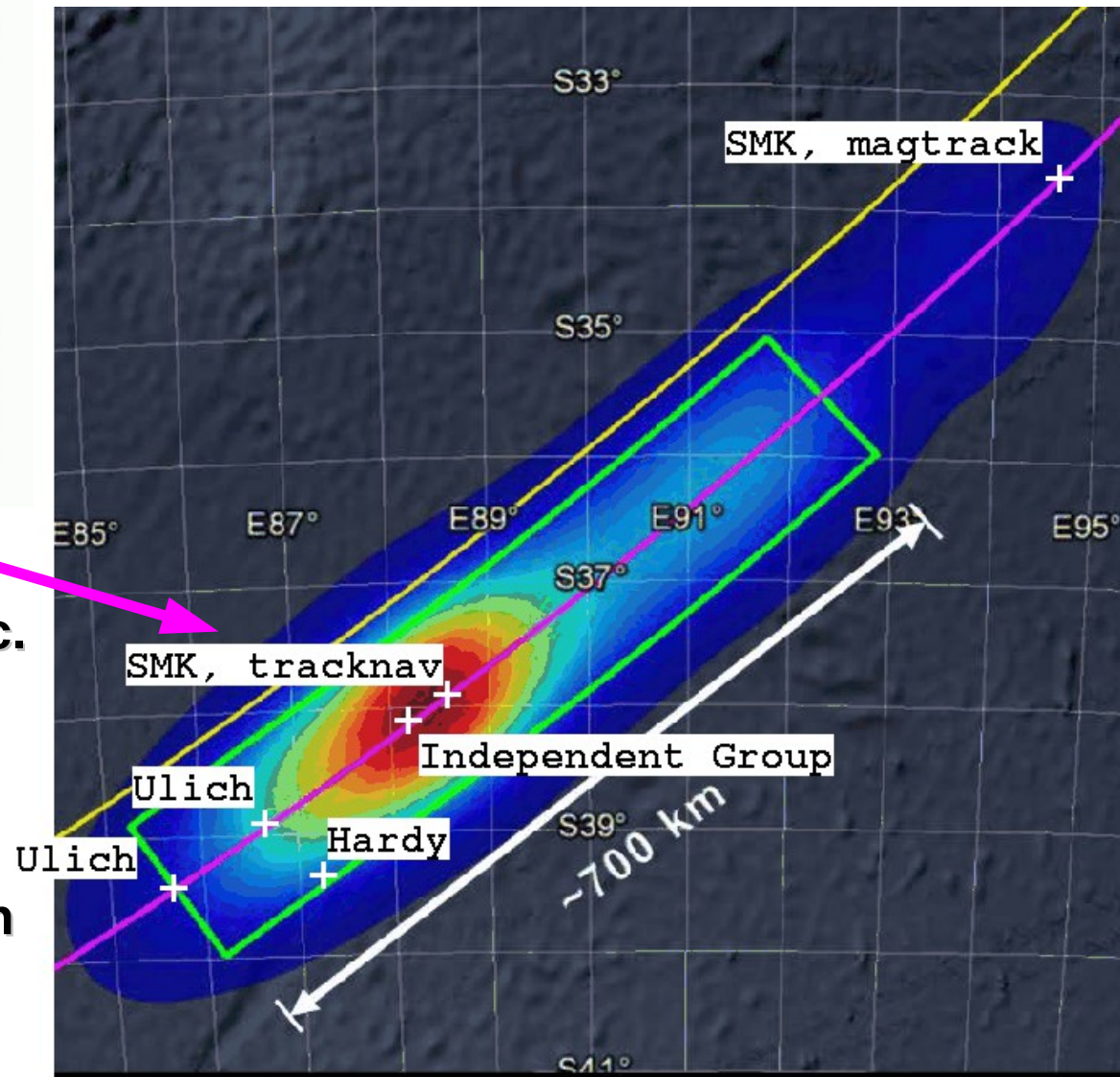
"The Routes Taken by Floating Debris from MH370" - R. Godfrey, Apr 2, 2016.

Predictions - JIT/JACC/ATSB v. Public



Early “official” search zones bounced up and down the 7th arc. Eventually settled on -35 to -39.

Nov 30, 2015: “Bayesian Methods in the Search for MH370” by DSTG. Highest probability region at -38° latitude.



Underwater Search (Australian ATSB lead)

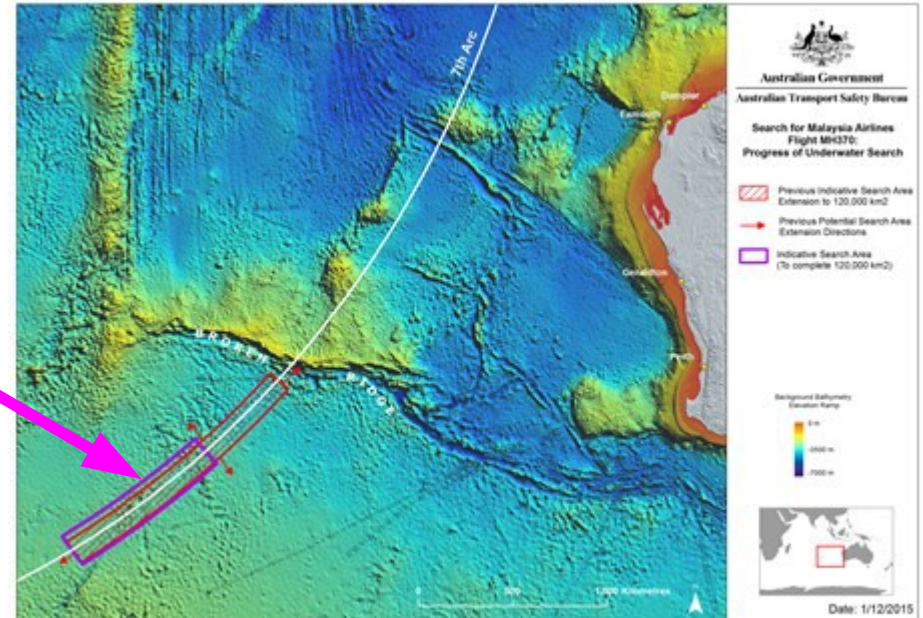
Currently 3 ships

Underwater search with towed side-scan sonar underway since Oct 2014.

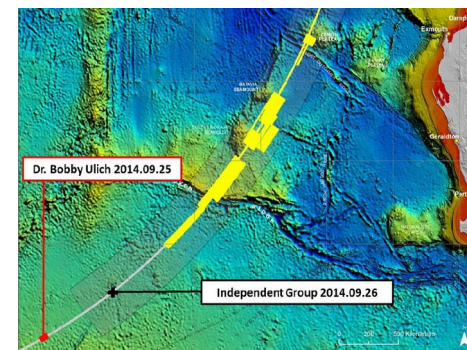
High priority search area 120,000 sq. km. Cost US \$100 million

Nothing found other than two unidentified shipwrecks.

Search will end ~July unless new evidence comes to light



Where are we now? Where do we go next?



Over a dozen people have modeled data.

Large parameter space (speed, heading, timing, altitude, fuel model, etc.)

Data-driven v. uncommanded autopilot-driven models

End-of-flight scenarios studied - one person used a genuine B-777 simulator.

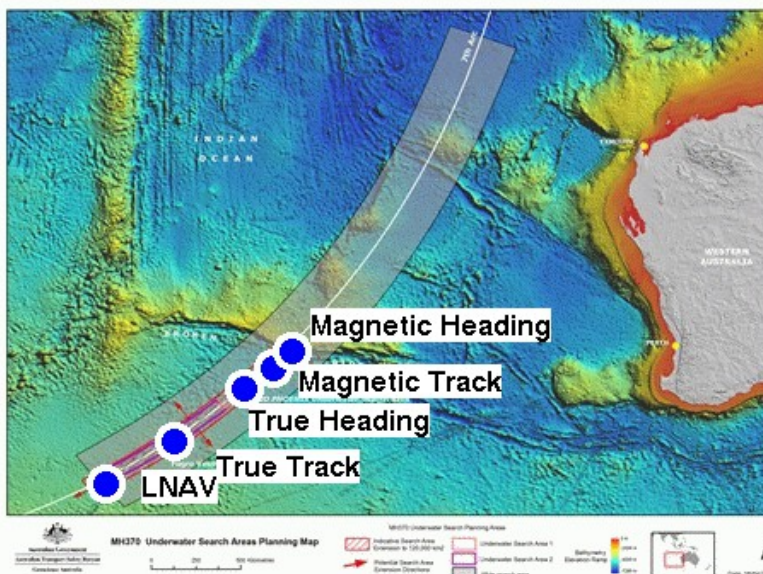
What if plane is not found?

Just missed in terrain?

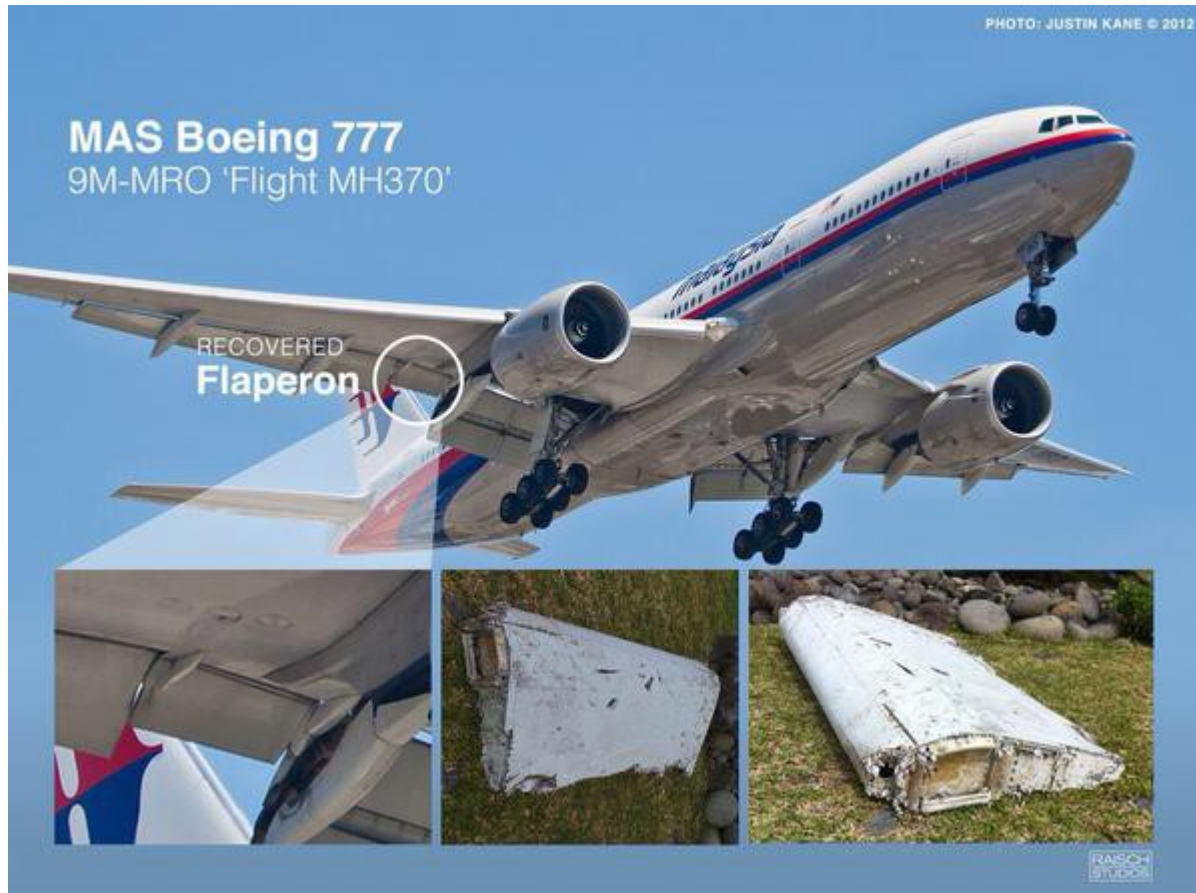
Revisit assumptions?

Actively piloted?

Conspiracy theory time!



IV. Breaking News ...



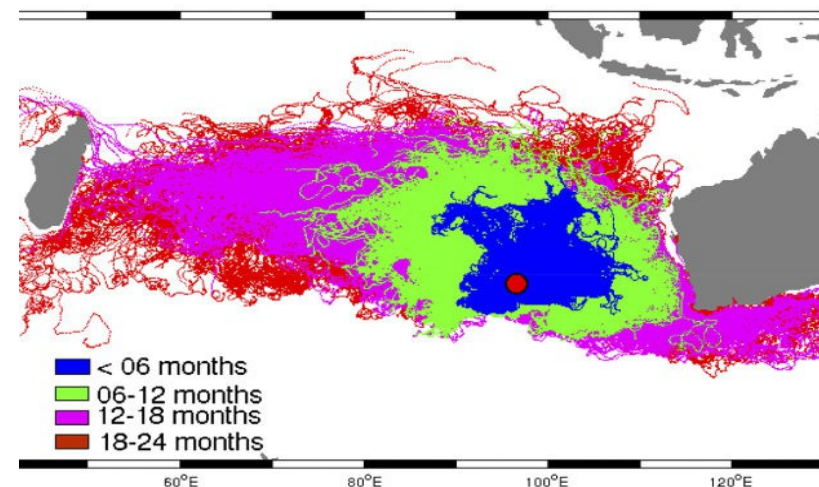
July 29, 2015 Piece of right wing (“flaperon”) discovered on Reunion Island, East of Madagascar.

(flaperon = flap + aileron)

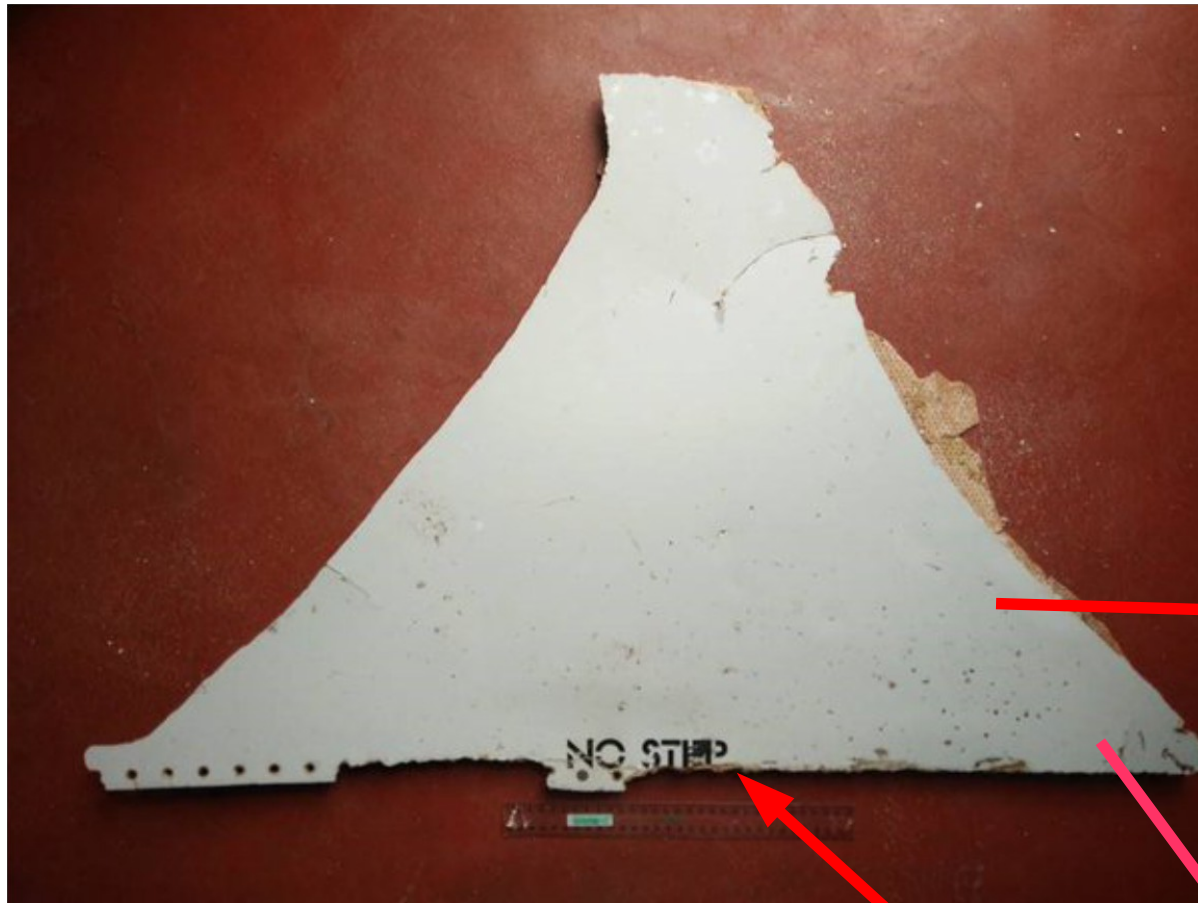
Confirming evidence that MH370 went down in South Indian Ocean

Drift modeling not accurate but favors more Northerly impact point

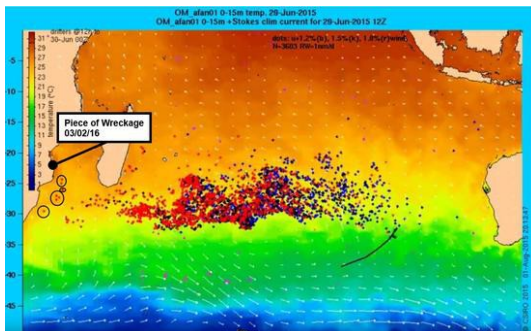
Goose barnacles - which species?



More Breaking News ...



Feb 27, 2016 Piece of right horizontal stabilizer discovered on sand bank off coast of Mozambique



Glaser stencil font

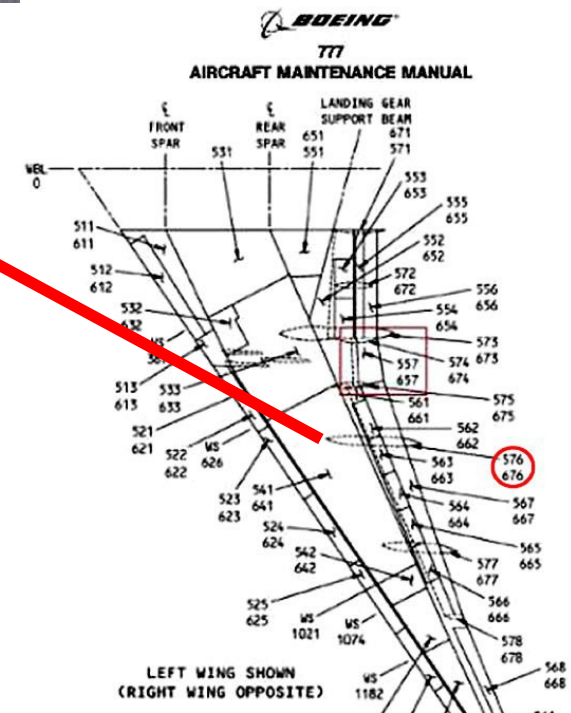
No Goose barnacles - why?



Further Breaking News ...



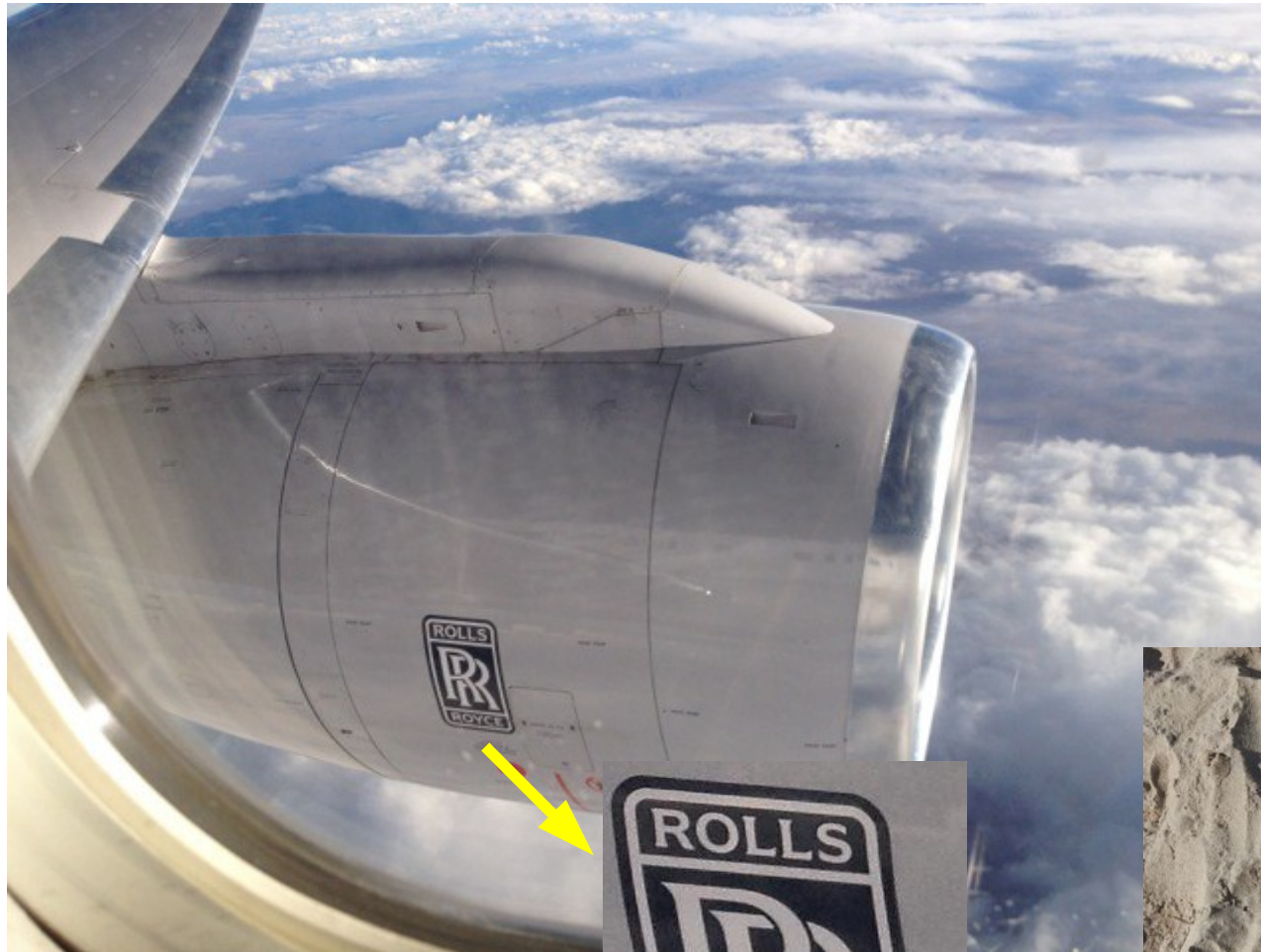
	Panel
676CR	Flap Support Fairing No. 7 Panel
676DB	Flap Support Fairing No. 7 Panel
676EB	Flap Support Fairing No. 7 - Aft
676FR	Flap Support Fairing No. 7 Panel
676GR	Flap Support Fairing No. 7 Panel
677AB	Flap Support Fairing No. 8 - Fwd



Mozambique, Dec 27, 2015.
676EB (Glaser Stencil Font) is B-777 outboard right wing flap track fairing.

Yet More Breaking News ...

Brenna Flaughter snapshot from plane window.



South Africa, Mossel Bay
Mar 22, 2016: Rolls Royce Engine logo
from engine cowling. Same size and
color scheme (grey letters on black
background) as 9M-MRO (MH370).



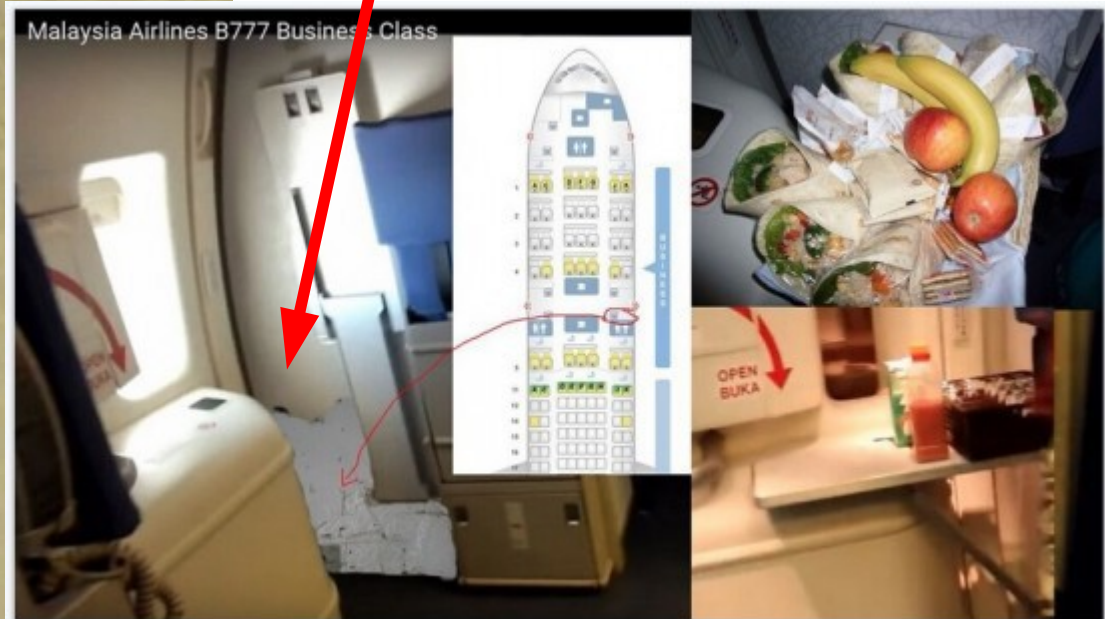
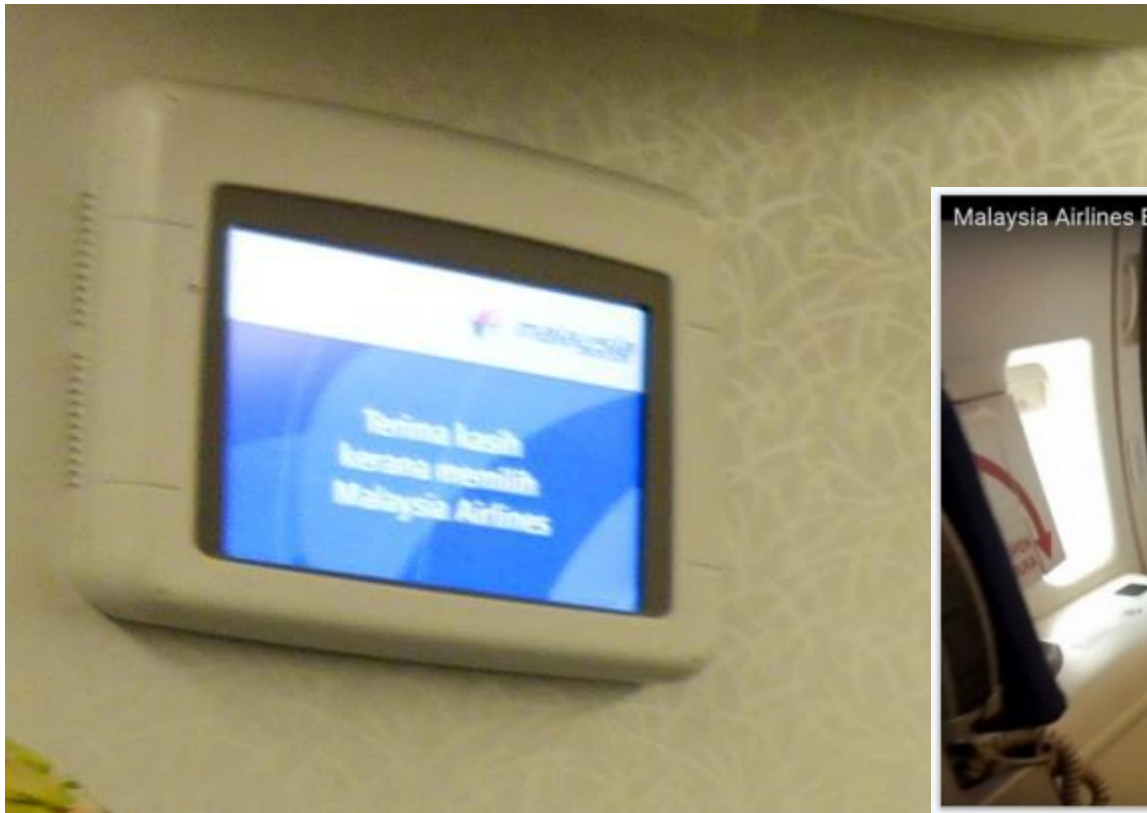
And Yet Still More Breaking News ...



Piece of debris from Rodrigues Island, Mauritius, March 30, 2016.

Intricate metallic design matches interior bulkhead of Malaysia Airlines fleet.

Location: Door 1R in business class.



And It Be Rainin' Debris!

Mauritius Bernache
May 24, 2016



Mauritius Gris Gris
May 25, 2016



Mozambique
May 26, 2016



**Macaneta,
Mozambique**
May 22, 2016



What Happened on Board?

We know more about Amelia Earhart than MH370

Much speculation about accident (fire) v. deliberate hijacking. Beyond scope of this talk.

Disabling Transponder

Disabling ACARS

Disabling SATCOM

Instrument bay

Power buses



V. Summary – Lessons Learned

Public can make serious use of data from complex systems. Do not underestimate!

In many ways, analysis of MH370 is similar to analyzing data from any experimental system:

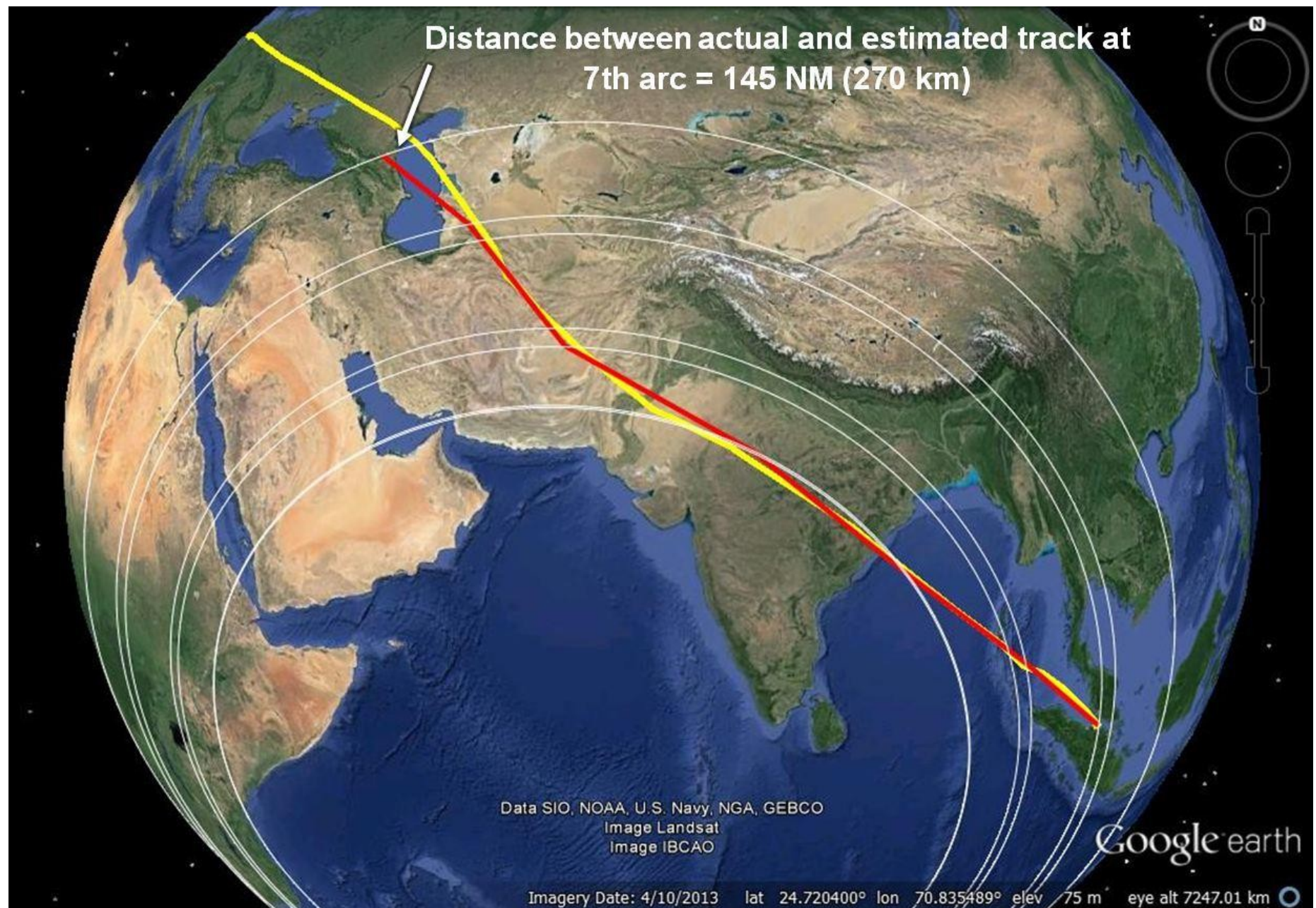
Must understand how each part of system works (requires documentation)

Calibration data are crucial

Do not hold back data that people might need - they will complain!

Backup Slides

MH21 - Kuala Lumpur to Amsterdam



MH21 - BFO

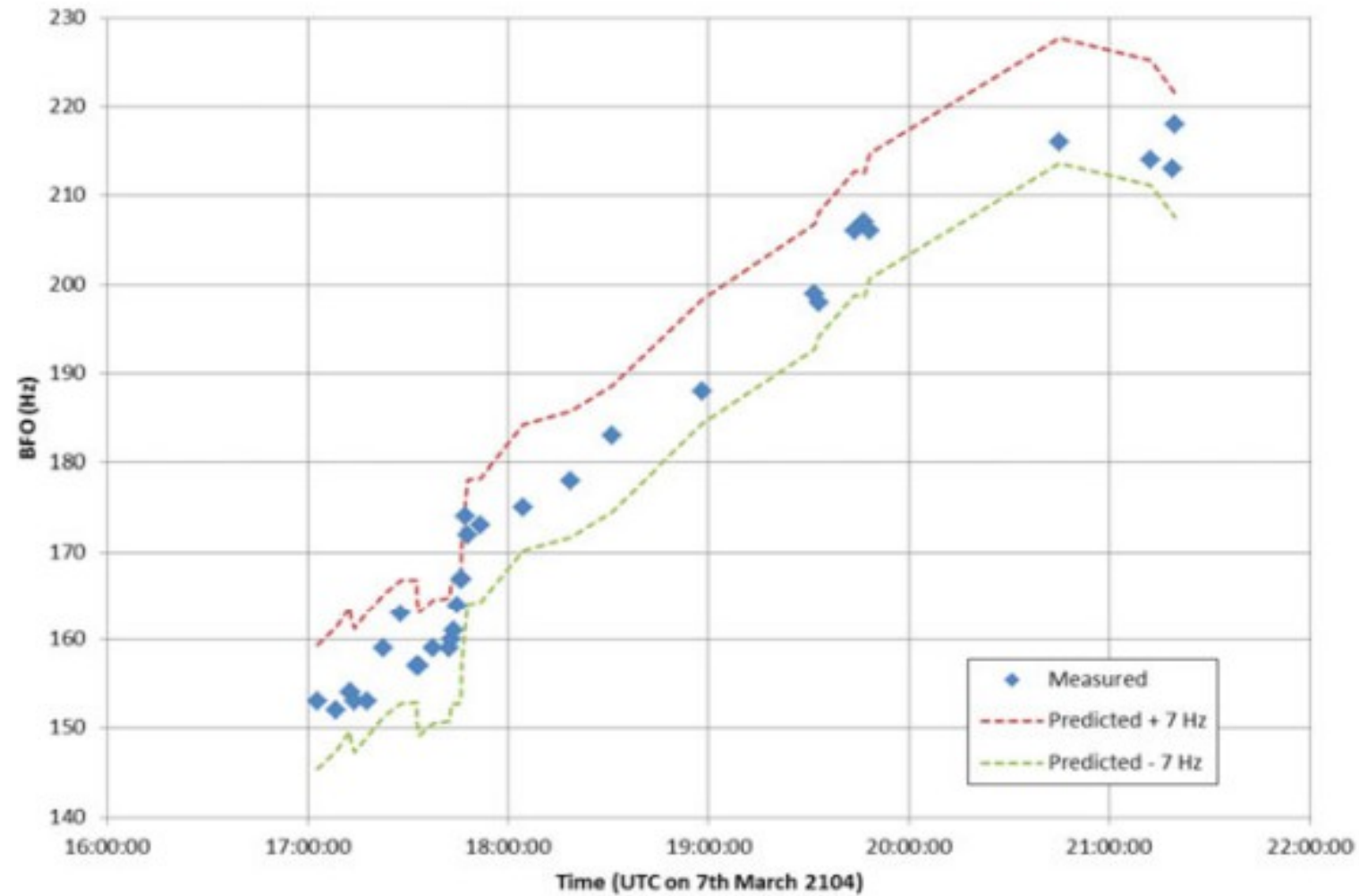


Figure 15. Burst Frequency Offset Validation (Amsterdam Flight).

Why no barnacles? ... Oh wait



December 23, 2014
Mossel Bay
Klein Brak Beach

March 22, 2014
Mossel Bay
Klein Brak River

Snails have done
their work



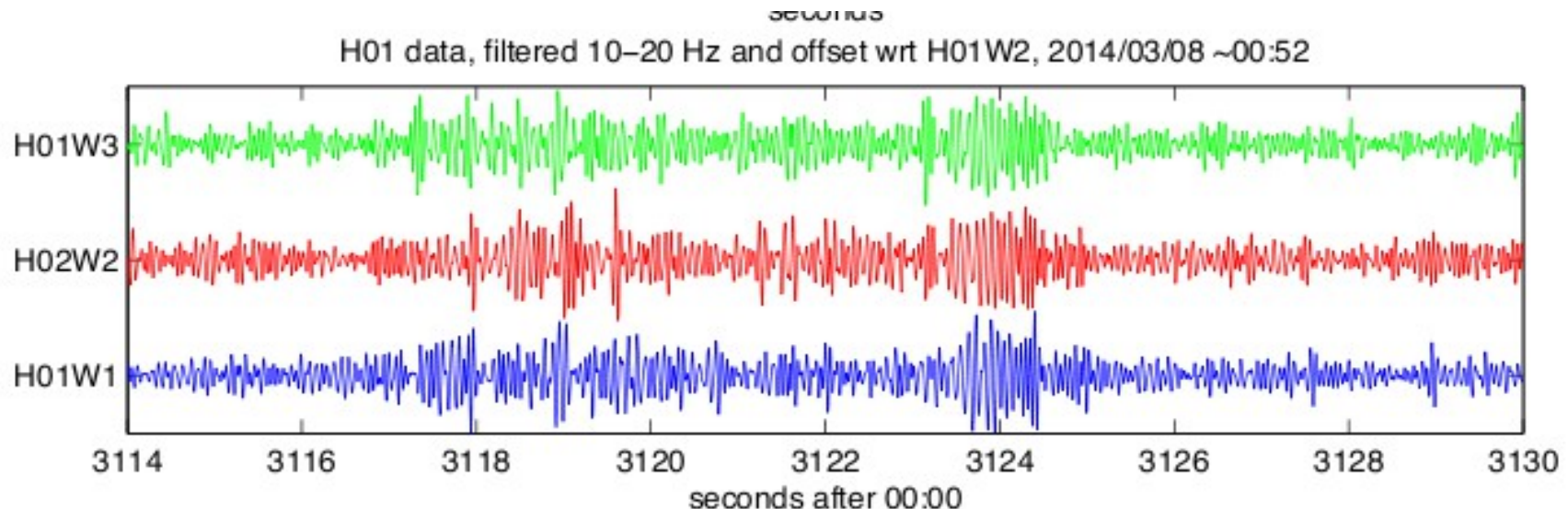
Recent Analysis - Did Anyone Hear It Crash?

Hydrophones

IMOS station Rottnest Island (W of Perth)

CTBTO station HA01 (Cape Leeuwin, Australia)

LANL claims detection at 00:52, bearing 246.9 deg



Recent Analysis - Did Anyone Feel It Crash?

Seismic stations

Geoscope (French) and others - 11 stations
around Indian Ocean

Data from IRIS-DMC

